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# Artillery firing

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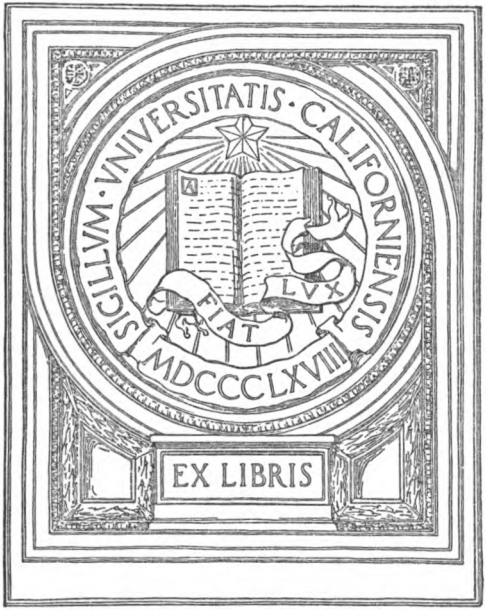

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# ARTILLERY FIRING

(Reprint of pamphlet translated by American Expeditionary Forces, France)

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WAR PLANS DIVISION
U.S. GENERAL STAFF

---

June, 1918

War Department
Document No. 808
(supersedes A. G. O. No. 762)
Office of the Adjutant General

WASHINGTON
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1918

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WAR DEPARTMENT.

Document No. 808.

Office of the Adjutant General.

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WAR DEPARTMENT,
WASHINGTON, *June 12, 1918.*

The following book, "Artillery Firing," a translation of the French "Instruction sur le Tir d'Artillerie," is published for the information and guidance of all concerned, as basic regulations in artillery firing.

The methods and terminology are general and are adopted as standard. Future editions of regulations for particular weapons will be in conformity with these regulations.

While a relatively large amount of the text is devoted to the complexities and refinements incident to position warfare, the rapid approximate methods of open warfare must not be neglected. The artillery must be able to adapt its methods to the situation, otherwise it can not hope to meet the demands which can reasonably be made upon it.

[062.1 A. G. O.]

BY ORDER OF THE SECRETARY OF WAR:

PEYTON C. MARCH,
*General, Chief of Staff.*

OFFICIAL:
H. P. McCAIN,
*The Adjutant General.*



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# ARTILLERY FIRING

## PREFACE.

**Extract from the report of the French Central Artillery Commission charged with the preparation of the "Projet d'Instruction sur le Tir d'Artillerie."**

The increase in the power of artillery which has taken place during the present war has brought about considerable changes in the fighting methods of the arm, and particularly in firing.

"Artillery Firing" is based on the following regulations and instructions:

Field Artillery Drill Regulations, September 8, 1910.

Drill Regulations for Foot Artillery. Provisional Firing Regulations, May 15, 1915.

Provisional Practical Methods for the Organization and Direction of Fire with Matériels of Long Range and Limited Horizontal Field of Fire, July 14, 1915.

Trench Artillery Drill Regulations. Provisional Firing Regulations, September, 1916.

Various notes and instructions, covering new and sometimes transient necessities, supplementary to the manuals already in force.

Many of this large number of publications are, in parts at least, obsolete, poorly coordinated, and based on controvertible principles. It therefore became necessary to coordinate the unavoidably divergent ideas and methods of these publications, and to explain new and improved methods.

In preparing the present publication, endeavor has been made to establish general and uniform methods for the preparation of fire and



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firing, setting forth the duties of the personnel. Methods already tested by experience have not been changed, except in case of well recognized necessity.

The general object is to develop the flexibility of artillery fire to the utmost, and increase its efficiency by reducing the ammunition consumption to a minimum.

The preparation of fire is dealt with in detail. The stress laid on the accurate preparation of fire must not be allowed to create the impression that fire for adjustment is not necessary, since an accurate adjustment can be secured only by firing.

The methods of fire are purposely made most general. The diversity of the tasks now assigned to artillery and the expansion of the resources at its disposal have greatly widened the scope of the activities of all classes of artillery. It appeared advisable to blend such of the methods of the various kinds of artillery as experience in war has shown to be sound. Thus the field artillery will be given the methods of the old foot artillery, which best meet the requirements of modern warfare in fire for material effect and demolition. On the other hand, heavy artillery will be supplied practical methods for rapid action when circumstances do not admit of long and minute calculations.

Moreover, it is to be noted that, while the tactical situation may make one method of fire preferable to another, the science of ballistics and the principles of fire are the same for all kinds and calibers of artillery.

The present publication should eliminate differences in principles and terminology pertaining to artillery, simplifying the training of officers, and bringing into more intimate association the various classes of the arm.

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# PART I.

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# CHAPTER 1.

## BALLISTICS.

### DEFINITIONS.

**1.** The **trajectery** is the curve described by the center of gravity of a projectile in flight.

The **origin of the trajectory** is the center of the muzzle.

The **line of departure** is the tangent to the trajectory at its origin.

The **quadrant angle of departure** (angle de projection) is the angle made by the line of departure with the horizontal.

2. **Elements at the beginning of the trajectory.**—The **line of elevation** is the axis of the bore prolonged when the piece is laid.

The **plane of fire** is the vertical plane through the line of departure.

The **quadrant elevation** is the angle between the line of elevation and the horizontal. In general, the projectile does not leave the bore on the line of elevation, but passes ordinarily a little above it.

The **jump** (angle de relèvement) is the angle made by the line of departure with the line of elevation.

For a given piece, the jump is taken as constant, whatever the elevation, for the same charge and projectile.[1]

For a given piece, the jump varies with the charge and projectile, and with the carriage.

For certain matériels, the jump is negative, that is, the line of departure is below the line of elevation.[2]

The jump is always small.

The algebraic sum of the quadrant elevation and the jump is the quadrant angle of departure.

---

[1] This has not been verified for quadrant elevations above 15°.

[2] With the 200 howitzer, for example, the jump is negative and about 25′.



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The **muzzle velocity** is the velocity of the projectile at the beginning of its flight.[1]

**3. Elements at the end of the trajectory.**—The **point of fall** (point de chute) is the end of the trajectory being considered.

In general, it is not at the same altitude as the piece. It is defined by its range, or horizontal distance from the muzzle, and by its **altitude** with respect to the muzzle. The altitude is positive when the point of fall is above the muzzle, and negative when the point of fall is below the muzzle.

The **line of site** is the line joining the point of fall and muzzle.

The **plane of site** is a plane containing the line of site and perpendicular to the plane of fire.

The **site** is the **angle** made with the horizontal by the plane of site.

These terms are equally applicable to an objective or any other point taken at the point of fall of a trajectory.

The site is positive for points above the muzzle and negative for points below the muzzle.

**4.** The **angle of impact** (angle de chute) is the angle between the tangent to the surface of the ground and the tangent to the trajectory at the point of fall.

The **elevation** (angle de hausse) is the angle between the line of elevation and the plane of site.

The **angle of departure** (angle de départ) is the angle between the line of departure and the plane of site.

The **angle of fall** (angle d'arrivée) is the angle between the plane of site and the tangent to the trajectory at the point of fall.

The **quadrant angle of fall** is the angle between the horizontal and the tangent to the trajectory at the point of fall.

Hence the following equations:

Quadrant elevation=Elevation+Site.

Angle of departure=Elevation+Jump.

Quadrant angle of departure=Angle of departure+Site.

Angle of fall=Quadrant angle of fall+Site.

Quadrant angle of impact=Quadrant angle of fall+Slope of ground at the point of fall.

---

[1] Strictly speaking, during the first few meters of its flight the projectile is still subjected to the action of the powder gases, and the velocity increases until the action of these gases ceases. The muzzle velocity refers to the maximum velocity imparted to the projectile by the action of the powder gases.

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The site and the jump are considered with their proper signs. The slope of the ground is taken as positive when the point of fall is on a **forward slope** (glacis) (sloping upward away from the piece) and negative when the point of fall is on a **reverse slope** (contre-pente) (sloping downward away from the piece.[1])

**5. The range** (portée) of a trajectory is the horizontal distance from the muzzle to the point of fall. The **slant range** in this case is measured along the line of site.

The **range** (distance de tir) of an objective is the horizontal distance from the muzzle to the objective. The slant range is measured along the line of site.

With material where the laying instrument is graduated in range, the **range setting** (hausse) (or simply range) is the value announced to be set off on this scale.

**6. Time fire.**—In time fire the projectile bursts, or is intended to burst, in air.

The **burst line of site, plane of site,** and **site** are as previously defined, considering the burst as the point of fall.

The **burst range** (distance d'éclatement) is the horizontal distance from the muzzle to the burst. The slant burst range is measured along the burst line of site. The **burst range in the plane of site** is also used, the plane of site referring to the objective.

The **burst interval** is the horizontal distance from the burst to the objective. The slant burst interval is the distance from the burst to the objective.

The **height of burst** (hauteur d'éclatement) is the angle between the burst plane of site and the plane of site of the base of the objective.

The **linear height of burst** is the distance in meters of the burst from the plane of site of the base of the objective. The height of burst is positive when the burst is above this plane of site and negative when below it.

The **altitude of burst** is referred to the base of the objective.

---

[1] In firing against a material object, the **angle of incidence** (angle d'incidence) is the term used for the angle between the tangent to the trajectory and the normal to the surface struck at the point of impact.

The **burst angle of fall** is the same as the angle of fall, if the burst is considered as the point of fall.



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FIG. 1.



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The normal height of burst (hauteur-type) is that for which the efficacy of an air burst is a maximum. It is stated for various conditions in paragraph 240.

**7.** The firing tables give the principal elements of the various trajectories. The values are for **horizontal trajectories;** that is, the origin and the point of fall are at the same altitude.

The **summit** of the trajectory is its highest point.

The **maximum ordinate** (flèche) is the height of the summit above the base.

The **ascending branch** is the part of the trajectory between the origin and the summit. The **descending branch** is the part between the summit and the point of fall.

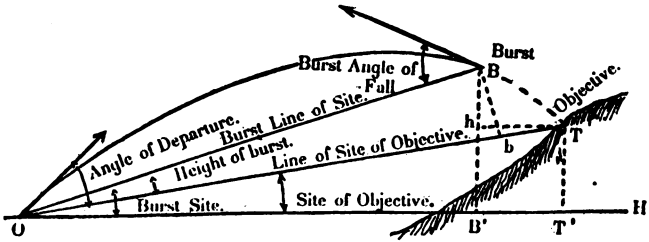


FIG. 2.

The **time of flight** (durée de trajet) is the length of the flight in seconds from the origin to the point of fall.

The tangential remaining velocity, or **remaining velocity,** is the velocity in meters per second of the projectile when it reaches the point of fall, or any other designated point, in the direction of the tangent to the trajectory at this point. The horizontal and vertical components of the remaining velocity are referred to as the horizontal and vertical remaining velocity.

The **inclination** of the trajectory at any point is the angle between the tangent to the trajectory at this point and the horizontal.

Horizontal remaining velocity=Remaining velocity×cos (inclination).

Vertical remaining velocity = Remaining velocity×sin (inclination).

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## STUDY OF THE TRAJECTORY.

**8.** The trajectory is tangent to the line of departure at its origin, but departs from it more and more [1] under the action of gravity. Gravity decreases the velocity of translation for the ascending branch and increases it for the descending branch. The resistance of the air [2] constantly decreases the velocity of translation of the projectile.

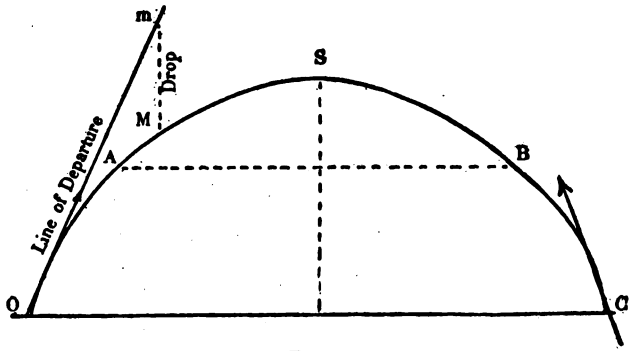


FIG. 3.

The trajectory **in vacuo** would be a parabola in a vertical plane, with its axis of symmetry a vertical line through the summit.

The projectile would twice pass through the horizontal plane AB at the points A and B (fig. 3).

At these two points the inclination and remaining velocity would be the same, and the time of flight for the portion AS would be the same as for SB.

The trajectory in vacuo would depend only on the muzzle velocity and the angle of departure. The weight, caliber, and form of the projectile would not affect it.

---

[1] The **drop** (abaissement) at any point is the **vertical** distance from the line of departure. It is due to gravity.

[2] Assumed calm.

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The horizontal remaining velocity would be the same for all points of it.

**9.** The trajectory in **air** differs from that in vacuo, because of the constantly retarding effect of the air resistance.

The projectile passes through horizontal plane AB, but the velocity at B is smaller and the inclination greater than at A. The time of flight from A to S is less than from S to B in spite of the fact that the distance AS is greater than SB. The descending branch is more curved than the ascending branch. The maximum ordinate is not an axis of symmetry, but is nearer the point of fall than the origin.

With respect to the velocity of translation, gravity and the air resistance have opposite effects for the descending branch.

After the projectile has passed the summit, gravity, which up to this point had acted with the air resistance to retard it, acts to restore velocity against the air resistance. The air resistance increases rapidly with the velocity of the projectile. If the flight is sufficiently long and conditions are suitable, it may happen that some time after passing the summit the projectile will begin to gain velocity, owing to the fact that the acceleration due to gravity is greater than the retardation due to the air resistance. As the velocity increases, the retardation of the air increases, and a point will finally be reached where the acceleration due to gravity will be equal to the retardation of the air. The projectile will then tend to maintain a constant velocity, modified only by the varying retardation due to the varying density of the air and by the varying acceleration of gravity due to the varying inclination of the trajectory.

**10.** The weight, caliber, and form of the projectile influences the air resistance. The trajectory in air depends then not only on the muzzle velocity and the elevation but on the characteristics of the projectile. The capacity of a projectile itself to overcome the resistance of the air is numerically expressed by what is known as the **ballistic coefficient.**[1]

In regard to the air resistance, it may be stated generally that:

(*a*) It increases with the velocity.

[1] The ballistic coefficient depends on the law of air resistance adopted. Those given in the recent firing tables are based on the publications of the Gavre Commission.

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(*b*) It increases inversely with the sectional density.[1]

(*c*) It varies materially with the form of the projectile.

Experiments have shown clearly that the long point and tapered base materially reduce the air resistance.

It follows that the heavy projectiles of the large calibers, with low muzzle velocities, are relatively little affected by the air resistance. Their trajectories in air approach those in vacuo.

Trench mortar projectiles have a trajectory nearly parabolic, but the wind and unsteadiness of the projectile cause material irregularities in flight.

**11.** In what precedes, it has been assumed that the trajectory is in the plane of fire, and, practically speaking, the line of departure is always in this plane. For smooth bores and in calm air, the projectile remains in the plane of fire. This is particularly true of the straight finned projectiles of trench mortars.

But for rifled bores, the air resistance and the rotation of the projectile cause the projectile to **drift,** or depart more and more from the plane of fire.

The **drift** (dérivation) for any point of the trajectory is the departure of this point from the plane of fire, either in linear units or in angular units measured from the origin (fig. 5).

For pieces rifled to the right (with a right-hand twist), the drift is to the right. For a left-hand twist, it is to the left.

The drift is given in the firing tables. For a given muzzle velocity, the drift increases with the rotational velocity, hence with the twist of the rifling. But it is always small, so that the trajectory may be taken as practically the same as its projection on the plane of fire; and except for the drift, the trajectory may be considered as though it were in the plane of fire.

**12.** The general form of the trajectory depends essentially on the ballistic coefficient of the projectile, the direction and velocity of its

---

[1] If $p$ is the weight of the projectile and $a$ its caliber, the sectional density is proportional to $\frac{p}{a^2}$.

Since for similar projectiles the weights are proportional to the cube of the calibers, it follows that, other things being equal, the large calibers lose velocity less rapidly than the smaller ones. For the same muzzle velocity, the large caliber has a greater range than the small one. Endeavor is made to increase the sectional density by elongating the projectile, but if this is carried too far the projectile becomes unstable.

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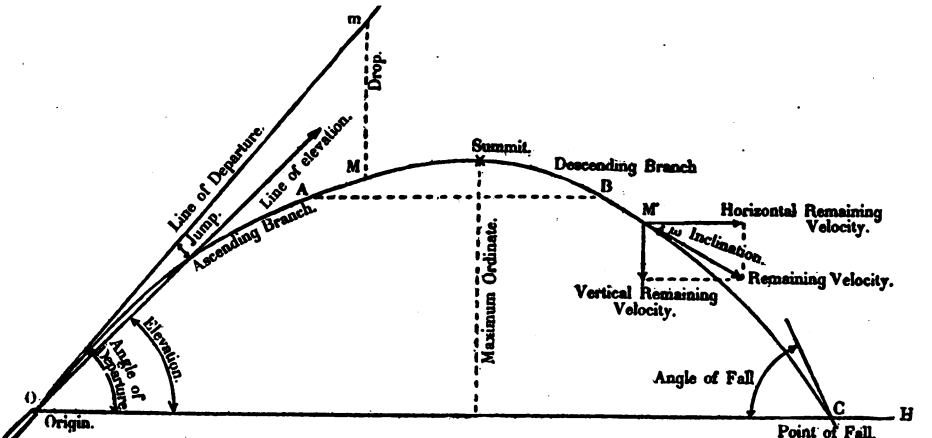


OC—Range.

FIG. 4.



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rotation, and, as will be later explained, the atmospheric conditions (wind and air density).

With these constant, the trajectory varies with the muzzle velocity and the elevation. The other elements follow from these.

If the angle of fall and the range, or the angle of fall and the remaining velocity, or the elevation and range, are known, the remaining elements are fixed and can be determined.

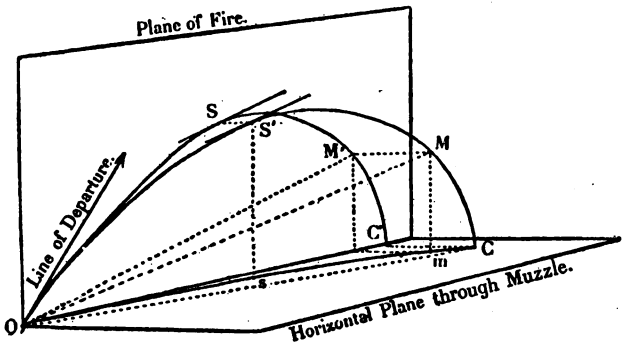


FIG. 5.

**13.** When one of the two principal elements, muzzle velocity and elevation, varies and the other remains constant the trajectory varies as follows:

**Muzzle velocity fixed.**—As the elevation increases from 0, the summit, maximum ordinate, angle of fall, and time of flight increase. The range increases up to a maximum at an elevation of nearly 45 degrees.[1] It then decreases to 0 for an elevation of about 90 degrees.

Any point at less than the maximum range can thus be reached by two elevations, one greater and one less than about 45 degrees.

[1] The maximum range in air for a horizontal trajectory is with an elevation between 40 and 45 degrees. The elevation approaches the more nearly to 45 degrees as the trajectory approximates that in vacuo (heavy projectile and low muzzle velocity).

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These two elevations approach each other as the range of the point considered approaches the maximum.

Fire at the greater elevation is called **high angle fire** (tir vertical), and at the lower, **flat or curved fire** (tir tendu ou plongeant) depending on the elevation.[1]

The **curve of security** (fig. 6) is the curve tangent to all trajectories which are possible when firing with a fixed muzzle velocity and direction. Every point under this curve can be reached by two trajectories and no more. Points above the curve can not be reached.

**Elevation fixed.**—As the muzzle velocity is increased, the range, the maximum ordinate, the remaining velocity, the angle of fall, and the time of flight also increase.

The muzzle velocity may be increased for the same powder by increasing the charge. But this increases the pressure, which is limited by the strength of the projectile, piece, brake, and carriage. The limiting quantity of motion (MV) depends on the muzzle velocity and the weight of the projectile and of the charge.

It is sometimes possible to obtain an increase of velocity with the same or a lesser maximum pressure by using a slower powder which gives a more sustained pressure. But too slow a powder burns poorly and gives irregularities in muzzle velocity.

An increase of muzzle velocity may also be obtained with the same charge by decreasing the powder chamber, but this likewise increases the pressure.[2]

## ANGULAR UNITS.

**14.** The angular units used by artillery vary according to the element measured and, to a certain extent, with the materiel.

They are:

The **quadrant,** or right angle.

The **degree,** with its subdivisions, the **minute** and **second.**

The **twentieth,** $\frac{1}{20}$ of a degree, or 3 minutes.

---

[1] Flat fire is at angles of fall less than 20 degrees. Curved fire is for elevations between 20 degrees and about 45 degrees.

[2] The Van Deuren trench mortar has a fixed elevation of 45 degrees. The range is varied by seating the projectile at varying points of the bore, thus varying the powder chamber.

The powder chamber is generally less for projectiles with the tapered base than for the ordinary shape. This explains why the muzzle velocity of the D shell is generally greater than the ordinary shape of the same weight, and with the same charge; and also why the D shell often can not be fired with the maximum charge.

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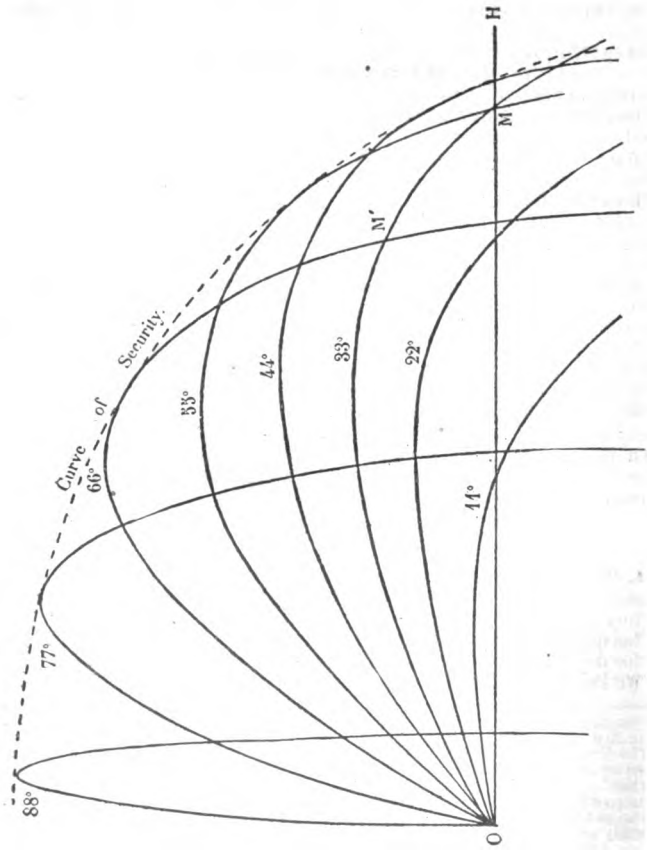


FIG. 6.

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The **grade,** $\frac{1}{100}$ of a quadrant, with its multiple, the **decagrade,** and subdivision, the **decigrade.**

The **mil,** $\frac{1}{6400}$ of a circle.

The mil is a working approximation to the **true mil.**

The true mil is an academic unit, being the angle subtended by a portion of the circumference equal to $\frac{1}{1000}$ of the radius, or nearly exactly, the angle whose sine or tangent is $\frac{1}{1000}$. This characteristic makes it very convenient for approximate calculations involving angles.

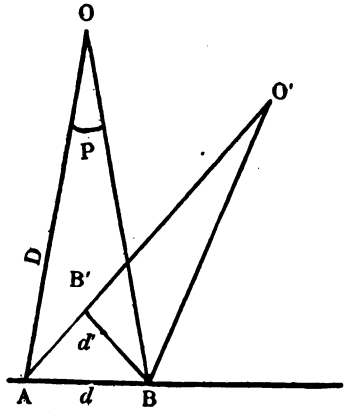


Fig. 7.

Since there are between 6283 and 6284 true mils in a circle, this unit is not practicable. By selecting a unit of nearly the same value as the true mil, and also a convenient fraction of a circle, a suitable working unit is obtained, without sacrificing the convenience of the true mil for approximate angular calculations.

Two units have thus come into use, the ordinary mil (called simply the mil) and the **R-mil.** The R-mil is $\frac{1}{6000}$ of a circle. The

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mil is thus seen to be the closer approximation to the true mil. The mil is slightly less than the true mil, and the R-mil slightly greater.[1]

**15.** Conversion from one angular unit to another can be made by means of the following equations:

90 degrees=1,000 decigrades=1,600 mils=1,500 R-mils=1,570.796 true mils. 1 degree=20 twentieths=60 minutes.

A mil is $3\frac{3}{8}$ minutes. There are approximately 18 mils to a degree.

For accurate angular conversions, it is generally more convenient to use the tables in Appendix 1.

**16.** The **angular distance** (écart angulaire) between two points A and B for an observer at O is the angle AOB (fig. 7).

This angle is also called the **parallax of 0 for AB.**

If the line AB is approximately normal to the lines OA and OB, this parallax is:

$$\frac{d}{D}, \text{ in mils,}$$

$$\text{or } \frac{d}{1.5D}, \text{ in decigrades.}^2$$

$d$ being the distance AB in meters, small with respect to OA and OB, and D the distance from O to AB in kilometers, which is practically equal to OA or OB.

If O′A and O′B are materially oblique to AB, $d'$ should be substituted for $d$, $d'$ being measured perpendicular to a line midway between O′A and O′B. The parallax is then computed by the same formulas as previously.

---

[1] The mil is $\frac{1}{1600}$ of a grade, or about $\frac{1}{360}$ of a degree. The R-mil is $\frac{1}{1500}$ of a grade, or about $\frac{1}{337.5}$ of a degree.

In the German and Russian firing tables, there is another angular unit approximately equal to the mil. It is the **sixteenth of a degree;** there are 5760 in the circle.

[2] Or more accurately, $\frac{d}{1.57\,D}$.

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## CHAPTER 2.

## DISPERSION—PROBABILITY OF FIRE.

### CAUSES OF DISPERSION.

**17.** When projectiles of the same kind are fired successively from the same piece, under conditions as nearly the same as possible, various causes affect their movement, and tend to produce appreciable differences between the shots.

It is important, from the standpoint of accuracy of fire, to differentiate, as far as conditions in practice permit, between the various causes of irregularity. The principal ones are discussed in the following paragraphs.

It may be remarked that conditions are never exactly the same throughout the firing of a series of shots.

**Projectiles.**—The acceptance inspection of empty shells, and the precautions taken in loading them, insure uniformity of exterior and interior form, weight, distribution of mass, and position of center of gravity.

**Exterior surface of projectiles.**—It has been found that slight differences in the exterior surface of projectiles have a considerable effect on the range and deflection, for example, the finish of the machined surface. The projectiles are carefully machined, and coated with paint, graphite, or coal tar, to protect from rust and dirt. Care must be taken to prevent abrasions and other damage during transport.

**Fuzes.**—Fuzes can be considered identical, from a ballistic standpoint, only when they are of the same weight and external form.[1]

**Charges.**—Effort must be made to have the charges of exactly the same weight. In making up reduced charges, care must be used to remove all loose bits of the removable bundles of powder.

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[1] The 24/31 percussion detonating fuzes, models 1899 and 1899–1908, for example, are identical from a ballistic point of view. This is not the case with the I fuze, model 1914, although it has the same weight as the other two and nearly the same shape.



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**Ballistic properties of the powder.**—The ballistic properties of a given powder lot are not always uniform within the lot, and there are differences between lots. Powder varies from time to time with the state of its moisture. This is an important cause of irregularity. Powder in bulk or made up in charges is frequently stored for a considerable time in dugouts or underground magazines which are damp, or in depots or cars where the temperature is elevated. Whenever possible, the charges for a battery should be supplied from powder of the same lot which has been kept under the same conditions.

**Method of loading.**—The charges should always have the same position in the chamber, and the projectiles should be seated at the same point of the forcing cone. Rotating bands must be protected against deformation. When a rammer is used, the force applied to it must be uniform.

**Laying.**—Accuracy in laying should be sought by careful training of the personnel, by frequent verification of their work, and by careful sight adjustment.

**Atmospheric conditions.**—The atmospheric conditions (air density, wind, etc.) may vary appreciably during even a short period of firing. The air resistance is a function of the air density, while the disturbances due to wind vary with the wind velocity.

The different causes which affect the flight of projectiles can be only partially eliminated. Projectiles fired successively from the same piece will always have slightly different trajectories, and hence there will always be **dispersion** in the points of fall.

This dispersion will be greater for the battery than for the individual pieces, because of differences in the calibration of the pieces. It is, therefore, important in firing to observe the shots of the individual pieces in order to adjust each of them properly.

**Sorting** (lotissement) **of projectiles.**—It is very necessary to sort the projectiles according to their weight. When they can not be segregated in lots of the same weight, they should be fired in the order of their weight, either increasing or decreasing (trench mortars).

### STUDY OF DISPERSION.

**18.** If a large number of shots be fired from the same piece under conditions as nearly identical as possible, the first few shots will appear to be dispersed in an irregular manner according to no fixed

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law. Gradually, as the number of shots increases, it will be noticed that the shots fall more frequently in a certain spot, and that the shots become more scattered as they are separated from this spot. The point about which the points of fall are grouped, and near which they are most dense, is called the **center of impact** or simply **center** (point moyen).

If the points of fall be referred to two rectangular axes of coordinates, OX and OY (fig. 8), the algebraic sum of the abscissæ divided by the number of shots will be the abscissa of the center, $M_1M$.

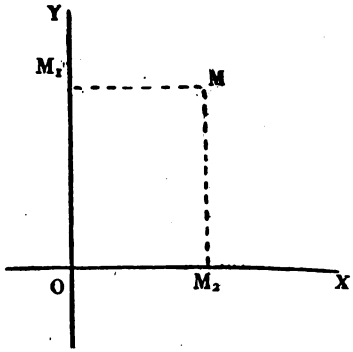


FIG. 8.

Similarly the algebraic sum of the ordinates divided by the number of shots will be equal to the ordinate of the center, $M_2M$. This affords a method of finding the center of the points of fall of a group of shots. But if the number of shots is limited, the position of the center thus found will not necessarily be the **true** one. It will, however, be the most probable one, and the best obtainable with the limited data available.

Let PM (fig. 9) be a line from the piece P through the center M, and AMB be perpendicular to PM. For a large number of shots half will fall to the right of PM and half to the left. Also, half will fall short of AB and half beyond.

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**19.** The **range error** (écart en portée) of a shot is the difference between its range and that of the center. In figure 9 the range error of R is RS. If R and M are not in the same horizontal plane, use instead of R the point where its trajectory pierces the horizontal plane through M.

Similarly the **deflection error** of R is SM, the distance of R from the line PM.

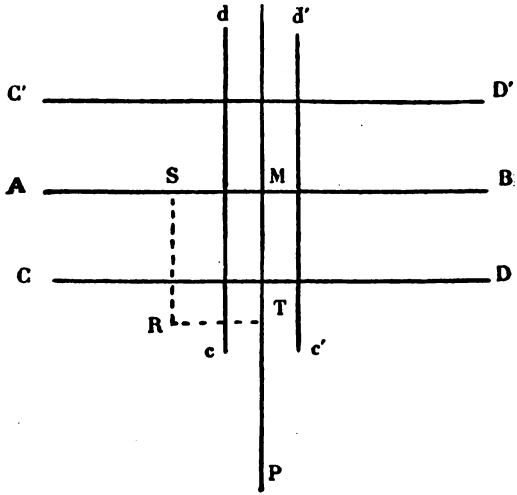


FIG. 9.

The **height error** of R is the difference between its height, when projected by its trajectory on the vertical plane through M, and the height of M.

The **range mean error** is the arithmetic mean of the range errors of all the shots. It is obtainable by adding the errors, without regard to sign, and dividing the sum by the number of shots. The **deflection mean error** and the **height mean error** are similarly obtained.

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Let C′D′ (fig. 9) be a line perpendicular to PM, so placed with respect to M as to include half of the shots beyond M, and CD be a similar line so placed as to include half of the shots short of M. If the number of shots is large, the lines C′D′ and CD will be equidistant from AB. The distance of C′D′, or CD, from AB is called the range probable error (écart probable en portée).

In the same manner *c′d′* and *cd* may be constructed, each at a distance from PM, which is the **deflection probable error.**

It follows from the preceding that the probable error is the error which, for a large number of events or in the long run, is as frequently exceeded as not.

The true value of the mean error and the true value of the probable error bear the following relation to each other:

$$\text{Probable error} = \text{Mean error} \times 0.8453.$$

This relation can be used to find the probable error from the mean error or its most probable value (par. 18). For a limited number of shots, this method of finding the probable error is only approximate.

**20.** In figure 10, M is the center. The line AB is a line through M perpendicular to the line of fire. The lines C′D′, CD, etc., are parallel to AB and separated by one range probable error.

It can be shown by the law of errors, which experience shows to be applicable to firing, that, if the **number of shots be very large,** nearly all (99 per cent) of the shots are included between the lines I′J′ and IJ, and that the various spaces will receive the percentages of shots indicated in the figure.

The zone between I′J′ and IJ, symmetrical with respect to AB and 8 probable errors in width, is called the **range zone of dispersion.**

The deflection and height zones of dispersion are similar.

**21.** The probable error is the measure of accuracy of fire; the smaller the probable error the more accurate is the fire.

The firing tables give the range and deflection probable errors, and by calculation, the height probable error, for various ranges and for a horizontal trajectory. The deflection and height probable errors increase with the range. This is also true in most cases of the range probable error.

For inclined trajectories, the probable error is taken the same as for horizontal trajectories.



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In firing against a forward or positive slope (par. 4), the range probable error **on the ground,** as can be seen from figure 11, is less than

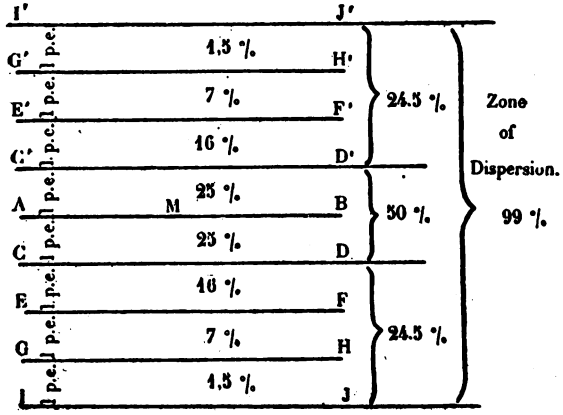


FIG. 10.

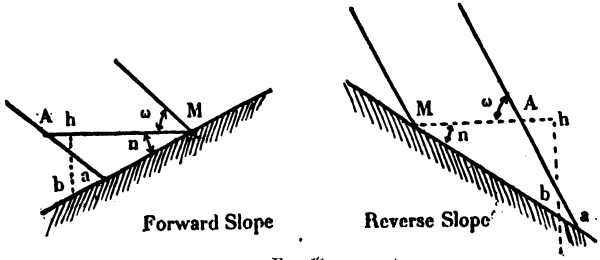


FIG. 11.

the range probable error proper. In firing against a reverse slope, the contrary is true.[1]

[1] Deflection probable errors are so small that, for practical purposes, the effect of a transverse slope on the deflection probable error on the ground may be neglected.

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## *Slope table.—Forward slope.*

| Quadrant angle of fall. | Slope in per cent or degrees. | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1% 35′. | 3% 1° ¾. | 5% 2° ¾. | 10% 5° ¾. | 15% 8° ½. | 20% 11° ½. | 25% 14°. | 30% 16° ¾. | 40% 21° ¾. | 50% 26° ½. | ∞ 90°. |
| 5° | 0.90 | 0.75 | 0.64 | 0.46 | 0.39 | 0.31 | 0.27 | 0.24 | 0.19 | 0.17 | 0.09 |
| 10° | 0.95 | 0.86 | 0.75 | 0.64 | 0.55 | 0.48 | 0.43 | 0.39 | 0.33 | 0.29 | 0.18 |
| 15° | 0.96 | 0.90 | 0.85 | 0.73 | 0.65 | 0.59 | 0.53 | 0.49 | 0.43 | 0.39 | 0.27 |
| 20° | 0.97 | 0.92 | 0.88 | 0.78 | 0.72 | 0.66 | 0.61 | 0.57 | 0.51 | 0.47 | 0.36 |
| 25° | 0.98 | 0.94 | 0.91 | 0.83 | 0.77 | 0.72 | 0.67 | 0.64 | 0.58 | 0.54 | 0.47 |
| 30° | 0.98 | 0.95 | 0.93 | 0.85 | 0.80 | 0.76 | 0.72 | 0.69 | 0.64 | 0.60 | 0.58 |
| 35° | 0.99 | 0.96 | 0.94 | 0.88 | 0.83 | 0.79 | 0.76 | 0.73 | 0.69 | 0.65 | 0.70 |
| 40° | 0.99 | 0.97 | 0.95 | 0.90 | 0.86 | 0.82 | 0.79 | 0.77 | 0.73 | 0.70 | 0.83 |
| 45° | 0.99 | 0.97 | 0.95 | 0.91 | 0.88 | 0.85 | 0.82 | 0.80 | 0.77 | 0.75 | 1.00 |
| 50° | 0.99 | 0.98 | 0.96 | 0.93 | 0.90 | 0.88 | 0.85 | 0.84 | 0.81 | 0.79 | 1.19 |
| 55° | 0.99 | 0.98 | 0.97 | 0.94 | 0.91 | 0.89 | 0.88 | 0.87 | 0.84 | 0.83 | 1.43 |
| 60° | 0.99 | 0.99 | 0.98 | 0.95 | 0.93 | 0.92 | 0.90 | 0.89 | 0.87 | 0.87 | 1.73 |
| 65° | 1.00 | 0.99 | 0.98 | 0.96 | 0.95 | 0.93 | 0.93 | 0.92 | 0.91 | 0.91 | 2.14 |
| 70° | 1.00 | 0.99 | 0.99 | 0.97 | 0.96 | 0.95 | 0.94 | 0.94 | 0.94 | 0.95 | 2.74 |
| 75° | 1.00 | 0.99 | 0.99 | 0.98 | 0.97 | 0.97 | 0.96 | 0.96 | 0.97 | 0.99 | 3.73 |
| 80° | 1.00 | 1.00 | 0.99 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 1.00 | 1.03 | 5.67 |

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*Slope table.—Reverse slope.*

| Quadrant angle of fall. | Slope in per cent or degrees. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1% 35′. | 3% 1° ¾. | 5% 2° ¾. | 10% 5° ¾. | 15% 8° ½. | 20% 11° ½. | 25% 14°. | 30% 16° ¾. | 40% 21° ¾. | 50% 26° ½. |
| 5° | 1.13 | 1.52 | 1.78 | | | | | | | |
| 10° | 1.06 | 1.21 | 1.39 | 2.38 | 6.70 | | | | | |
| 15° | 1.04 | 1.13 | 1.23 | 1.63 | 2.31 | 4.04 | 5.20 | | | |
| 20° | 1.03 | 1.09 | 1.16 | 1.39 | 1.73 | 2.26 | 3.26 | 5.90 | | |
| 25° | 1.02 | 1.07 | 1.14 | 1.29 | 1.49 | 1.79 | 2.22 | 2.92 | 7.57 | |
| 30° | 1.02 | 1.06 | 1.09 | 1.22 | 1.36 | 1.56 | 1.81 | 2.16 | 3.51 | 8.35 |
| 35° | 1.01 | 1.05 | 1.08 | 1.18 | 1.28 | 1.49 | 1.60 | 1.82 | 2.51 | 3.91 |
| 40° | 1.01 | 1.04 | 1.07 | 1.14 | 1.23 | 1.34 | 1.47 | 1.63 | 2.06 | 2.77 |
| 45° | 1.01 | 1.03 | 1.05 | 1.12 | 1.19 | 1.28 | 1.37 | 1.49 | 1.79 | 2.24 |
| 50° | 1.01 | 1.03 | 1.05 | 1.10 | 1.16 | 1.23 | 1.30 | 1.40 | 1.62 | 1.93 |
| 55° | 1.01 | 1.02 | 1.04 | 1.06 | 1.13 | 1.19 | 1.25 | 1.32 | 1.50 | 1.72 |
| 60° | 1.01 | 1.02 | 1.03 | 1.06 | 1.12 | 1.15 | 1.20 | 1.27 | 1.40 | 1.57 |
| 65° | 1.00 | 1.01 | 1.03 | 1.05 | 1.09 | 1.12 | 1.17 | 1.22 | 1.32 | 1.47 |
| 70° | 1.00 | 1.01 | 1.02 | 1.44 | 1.07 | 1.10 | 1.13 | 1.17 | 1.26 | 1.37 |
| 75° | 1.00 | 1.01 | 1.02 | 1.04 | 1.05 | 1.08 | 1.11 | 1.14 | 1.20 | 1.25 |
| 80° | 1.00 | 1.01 | 1.01 | 1.03 | 1.04 | 1.06 | 1.08 | 1.10 | 1.16 | 1.23 |

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The relation between the two probable errors is:

Range probable error on the ground=range probable error $\times \lambda$, where $\lambda$ is the **slope coefficient,**[1] a function of the slope of the ground and the quadrant angle of fall at the center.

Fire against a vertical surface may be considered as against a forward slope of 90 degrees. The range probable error on the ground is then the height probable error, so that:

Height probable error=range probable error $\times\lambda$ for 90 degrees.

The two tables herewith give the slope coefficient as a function of the slope $n$, in degrees or per cent, and the quadrant angle of fall of the trajectory. The first is for forward slopes, including 90 degrees, and the second for reverse slopes.

**22.** The values of the probable errors given in the firing tables are obtained experimentally [2] at proving grounds, under conditions which make for accuracy and which generally do not obtain in practice (selected ammunition, constant atmospheric conditions, or nearly so, shots rejected if they are unfavorable, etc.). The probable errors actually obtained in service are then generally greater than the proving ground values.

---

[1] Considering the sign of the slope, we have for both forward and reverse slopes (fig. 11):

$$\lambda=\frac{aM}{AM}=\frac{\sin\omega}{\sin(\omega+n)}.$$

Where $n$ is the slope and $\omega$ is the quadrant angle of fall in angular units. The slope $n$ in per cent may be computed with the aid of the map.

$$n=\frac{b}{hM}\frac{h}{}\times 100.$$

A slope in per cent may be converted into one in degrees by means of the slope tables herewith, using the dual values given for the slope.

For a forward slope, the range probable error on the ground may be greater than the range probable error when $\omega$ is greater than

$$90°-\frac{n}{2}.$$

For a slope less than 50 per cent, $\omega$ must be greater than 77 degrees; $\omega$ must always be greater than 45 degrees.

[2] The probable errors given in tables issued by the French Navy are generally obtained by calculation from the various elements affecting dispersion. They are ordinarily as great as the field probable errors, and sometimes greater.

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It is customary to assume the **field probable error** (écart probable pratique) as one and one-half times the tabular value.[1]

The values of the fork (par. 215) given in the firing tables correspond to 4 field range probable errors, or to 5 or 6 tabular range probable errors.

If a battery in service finds by experience that, due to the state of its matériel and ammunition or to exceptional skill of the personnel, its probable error is approximately that of the proving ground, the fork used should be taken accordingly.

**23. Dispersion in Time Fire.**—The laws of dispersion, explained in the case of percussion fire, are also applicable to time fire.

When projectiles of the same kind, and armed with the same fuse, are fired from the same piece so as to burst in air, with conditions as nearly the same as possible for all shots, it will again be found that the bursts will be grouped about a center, where they will be less scattered than anywhere else.

With the errors of the trajectory already discussed are mingled the errors due to irregularities in the fuse action. The latter cause the projectile to burst higher or lower on the trajectory.

The principal causes of fuse irregularities are:

**The fuse itself.**—In time fire, every effort should be made to use fuses of the same lot and which have been stored under the same conditions.

**Fuse setting.**—Irregularities in fuse setting should be reduced as much as possible by training the personnel and by using the fuse setter.

**24.** If the positions of the air bursts are projected perpendicularly on a horizontal plane or on a vertical plane, the same dispersion will be found as is discussed in paragraph 18. The position of the center, called the **burst center** in this case, may be found in the manner described. The **height of burst mean error** and the **range of burst mean error** may be found as described in paragraph 19, and from them the corresponding probable errors may be obtained.

---

[1] Experience shows that the wear of pieces, as long as it is not excessive, results in a gradual loss of muzzle velocity and hence range. But it does not materially affect the accuracy, or the probable error. Until the piece is so worn as to require relining, the usual values of the probable error are applicable.

Some firing tables give the height of burst and range of burst probable errors.

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*Probability table.*

| r. | Probability. | r. | Probability. | r. | Probability. | r. | Probability. |
|---|---|---|---|---|---|---|---|
| 0.00 | 0.000 | 1.00 | 0.500 | 2.00 | 0.823 | 3.00 | 0.957 |
| 0.05 | 0.027 | 1.05 | 0.521 | 2.05 | 0.833 | 3.05 | 0.960 |
| 0.10 | 0.054 | 1.10 | 0.542 | 2.10 | 0.843 | 3.10 | 0.964 |
| 0.15 | 0.080 | 1.15 | 0.562 | 2.15 | 0.853 | 3.15 | 0.966 |
| 0.20 | 0.107 | 1.20 | 0.582 | 2.20 | 0.862 | 3.20 | 0.969 |
| 0.25 | 0.134 | 1.25 | 0.601 | 2.25 | 0.871 | 3.25 | 0.972 |
| 0.30 | 0.160 | 1.30 | 0.619 | 2.30 | 0.879 | 3.30 | 0.974 |
| 0.35 | 0.187 | 1.35 | 0.637 | 2.35 | 0.887 | 3.35 | 0.976 |
| 0.40 | 0.213 | 1.40 | 0.655 | 2.40 | 0.895 | 3.40 | 0.978 |
| 0.45 | 0.239 | 1.45 | 0.672 | 2.45 | 0.902 | 3.50 | 0.982 |
| 0.50 | 0.264 | 1.50 | 0.688 | 2.50 | 0.908 | 3.60 | 0.985 |
| 0.55 | 0.289 | 1.55 | 0.704 | 2.55 | 0.915 | 3.70 | 0.987 |
| 0.60 | 0.314 | 1.60 | 0.719 | 2.60 | 0.921 | 3.80 | 0.990 |
| 0.65 | 0.339 | 1.65 | 0.734 | 2.65 | 0.926 | 3.90 | 0.992 |
| 0.70 | 0.363 | 1.70 | 0.749 | 2.70 | 0.931 | 4.00 | 0.993 |
| 0.75 | 0.387 | 1.75 | 0.762 | 2.75 | 0.936 | 4.20 | 0.995 |
| 0.80 | 0.411 | 1.80 | 0.775 | 2.80 | 0.941 | 4.40 | 0.997 |
| 0.85 | 0.434 | 1.85 | 0.788 | 2.85 | 0.945 | 4.60 | 0.998 |
| 0.90 | 0.456 | 1.90 | 0.800 | 2.90 | 0.950 | 4.80 | 0.999 |
| 0.95 | 0.478 | 1.95 | 0.812 | 2.95 | 0.953 | 5.00 | 0.999 |

**25. Safety Zone.**—In firing close to friendly troops, particularly in fire to accompany attacks, it is very important to place the **centers** sufficiently beyond the troops as not to endanger them. The space between the center and the friendly troops is called the **safety zone.** The safety zone must be as wide at least as half the zone of dispersion, increased by the distance to which dangerous fragments may be thrown. For fire perpendicular to the front, use 4 range probable errors in percussion fire, or 4 range of burst probable errors in time fire. For fire parallel to the front, use 4 deflection probable errors.

If there is a mask near the points of fall, the safety zone must be increased so as to clear this mask, in order to avoid premature bursts due to projectiles striking the mask.

In firing against a reverse slope, particularly at short range and with flat trajectories, the safety zone must be very deep.

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## PROBABILITY OF FIRE.

**26.** The probability of an event happening is the ratio of the numbers of cases in which the event happens, in the long run, to the total number of cases, all cases being equally likely to result in the event considered. Probability is always less than unity, or unity. When the probability is unity, the event is certain to happen.

If it is possible for two or more events to happen entirely independently of each other, the happening of one having no influence on the happening of the other, the probability that all will happen simultaneously is the **product** of the probabilities of the separate events happening.

Referring to the diagram of dispersion (fig. 10), it will be seen that the probability of a shot falling in the space ABCD is .25, since, in the long run, .25 of all shots fired fall in this space.

The probability of a shot having an error less than a given value is the ratio of the number of shots having errors less than the given value to the total number of shots in a series indefinitely prolonged.

Probability may be expressed by a fraction, a decimal, or in per cent.

The table on page 36, based on the law of errors (par. 20), gives the probability, as a decimal, of an error less than $r$ times the probable error. It is applicable to all classes of errors.

**27.** This table permits the solution of various problems frequently arising in practice, in which it is desired to find the probability of hitting a given objective.

**Examples.**—(1) In prolonged firing, what is the probability of hitting a zone of width $a$ and perpendicular (or parallel) to the plane of fire? The center is at the center of the width of the zone (fig. 12).

**Solution.**—Let $e_p$ be the range (deflection) probable error.

$$\text{Then } r=\frac{a}{2e_p}.$$

The probability sought is then taken directly from the probability table, as a decimal, which can be multiplied by 100 to give the value in per cent.

(2) In prolonged firing, what is the probability of hitting a space, of width $b$ and perpendicular (or parallel) to the plane of fire? The space is at a distance $a$ from the range (deflection) center (fig. 13).

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**Solution.**—Let LL and KK be the limits of the space, and K′K′ and L′L′ be a similar space constructed so that the two spaces will be symmetrically disposed with respect to the center M.

Determine the probability of hitting the space LL, L′L′, as in example **1**, and the probability of hitting the space KK, K′K′. The difference between these two probabilities, divided by two, will be the probability sought.

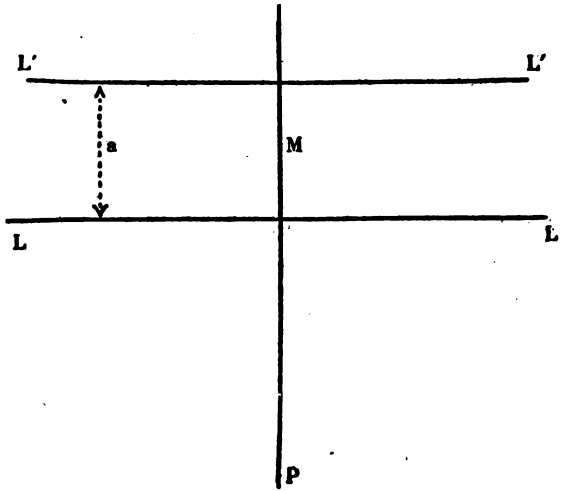


FIG. 12.

**(3)** In prolonged firing, what is the probability of hitting a rectangle, whose sides are respectively perpendicular and parallel to the line of fire, and whose center occupies a given position with respect to the center of impact?

**Solution.**—Let $a$ and $b$ be the dimensions of the rectangle. Find, as in the preceding examples, the probability of hitting a space $a$

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wide and indefinite in extent in the direction of $b$. Similarly find the probability of hitting a space $b$ wide and indefinite in extent in the direction of $a$. The **product** (par. 26) of these two probabilities will be the probability sought.

(4) Firing with a 280 mortar. Range, 6,000 meters. Base fuzed shell, charge 3. Objective, a concrete work of 5×12 meters hori-

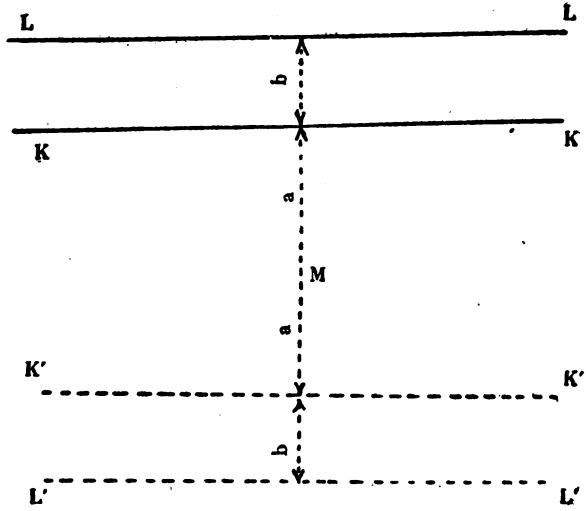


FIG. 13.

zontal dimensions, with the longer dimension perpendicular to the plane of fire. The fire is assumed to be perfectly adjusted, that is, the center is at the center of the objective (fig. 14). What is the probability of hitting this objective in prolonged firing?

**Solution.**—From the firing tables of September, 1915, it is found that the range probable error is 20 m. 6, and the deflection probable

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error is 3 m. 1. Take the tabular probable errors as directly applicable.

For the space 5 meters wide in range and indefinite in width,

$$r=\frac{5}{2\times 20.6}=.12 \text{ and } p=.065.$$

For the space 12 meters wide in deflection and indefinite in width,

$$r=\frac{12}{2\times 3.1}=1.93 \text{ and } p=.807.$$

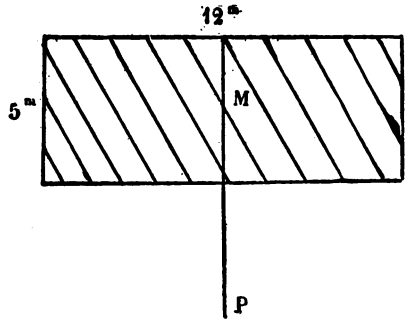


FIG. 14.

The probability sought is then $.065\times.807=.052$, or about 5 per cent. Then, in prolonged firing, about one shot in twenty would hit the objective. But, for a limited number of shots, the number of hits might vary considerably from this proportion.

(5) For a perfectly adjusted fire, what is the probability of hitting a rectangle whose sides are respectively twice the range and deflection probable error?

The probabilities for range and for deflection are each .50. Hence the probability sought is $.50\times.50=.25$, or 25 per cent.

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*Rectangle of dispersion.*

| 1.5 | 7 | 16 | 25 | 25 | 16 | 7 | 1.5 | |
|---|---|---|---|---|---|---|---|---|
| % 0.02 | % 0.10 | % 0.24 | % 0.38 | % 0.38 | % 0.24 | % 0.10 | % 0.02 | % 1.5 |
| 0.10 | 0.49 | 1.12 | 1.75 | 1.75 | 1.12 | 0.49 | 0.10 | 7 |
| 0.24 | 1.12 | 2.56 | 4.00 | 4.00 | 2.56 | 1.12 | 0.24 | 16 |
| 0.38 | 1.75 | 4.00 | 6.25 | 6.25 M | 4.00 | 1.75 | 0.38 | 25 |
| 0.38 | 1.75 | 4.00 | 6.25 | 6.25 | 4.00 | 1.75 | 0.38 | 25 |
| 0.24 | 1.12 | 2.56 | 4.00 | 4.00 | 2.56 | 1.12 | 0.24 | 16 |
| 0.10 | 0.49 | 1.12 | 1.75 | 1.75 | 1.12 | 0.49 | 0.10 | 7 |
| 0.02 | 0.10 | 0.24 | 0.38 | 0.38 | 0.24 | 0.10 | 0.02 | 1.5 |

**28.** If diagrams of dispersion (par. 20) be constructed with respect to a center M, for both range and deflection, the **rectangle of dispersion** will be obtained. By its construction, the rectangle will be divided into 64 smaller rectangles, each one deflection probable error by one range probable error in size. (See diagram.)

By the methods already explained, the probability of hitting each of the small rectangles can be calculated. These probabilities are given in the diagram.

But, for a **limited** number of say 100 shots fired, it is not certain that they will be distributed in the proportions shown. Even though the number of shots fired is very considerable, there is no absolute assurance that the number of hits predicted by the application of probability will actually be obtained. Observation of the

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fire will always be necessary to make sure that the desired result has been attained. With the limited number of rounds fired on even very important objectives in service, the application of probability can only be relied upon to furnish an approximation as to the ammunition which must be provided to accomplish a given result.

To determine the number of rounds to be provided to attack a given objective, the methods of calculation already explained may be used, or the result may be obtained graphically. For the latter method, construct a rectangle of dispersion to the scale of the map being used. Place it on the map, correctly oriented, and with the center suitably located with respect to the objective. The probabilities for each of the small rectangles which lie within the limits of the objective are then added. The sum is the probablity of a shot fired hitting the objective. The number of rounds to be allotted is then obtained by dividing the number of hits desired by the probability of one hit.

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## CHAPTER 3.

## FIRING TABLES AND THEIR USE.

**29.** Firing tables give the principal elements of the trajectory for the different projectiles which may be fired in a piece.

The data contained in them is based on:

A new gun.[1]

A medium powder lot,[2] at 15° C temperature, and for mean annual conditions.[3]

Projectiles all having a certain weight and model of fuze.

Absence of wind.

Weight of a liter of air at the battery position of lg. 208.

Horizontal trajectory (par. 7).

**30.** Generally, for each projectile, several charges of different weights and sometimes different kinds can be used.

For each of the various charges there is a tabular muzzle velocity on which the firing tables are based.[4]

---

[1] On account of the tolerances which are necessary in manufacture, no two guns are exactly alike. There are slight variations in the powder chamber, the depth of the grooves, and the diameter of the bore, so that the velocities vary slightly, even if external conditions are constant. These variations are increased if two pieces are not worn to the same extent.

[2] The characteristics of powder are such that certain not inconsiderable tolerances must be allowed on acceptance. A quick powder lot is one which gives greater than the tabular velocity with the standard charge. A slow lot gives less than the tabular velocity with the standard charge. A medium lot is one giving the tabular velocity with the standard charge. For BC powder, the standard charge must give the tabular velocity within 10 meters; for BGP powder, within 15 meters, and for $BG_6$, within 20 meters. For BM powder, the standard charge must give a velocity not less than a certain limit, and the pressure must not exceed a certain amount.

[3] A given lot of powder fired in the same piece, under conditions as nearly identical as possible, gives greater velocities in summer than in winter. The mean annual velocity for a certain charge and lot is the mean of the velocities which it gives in various seasons. The mean annual velocity is obtained toward the end of spring and autumn.

[4] This is only true when a constant powder chamber is used. An exception is the Van Deuren trench mortar (par. 13).



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Projectiles having the same weight, but different fuzes, will, other conditions being the same, have the same muzzle velocity. But the trajectories will be the same only when the fuzes have the same external form.[1]

**31.** The firing tables give, for the various projectiles, fuses, and muzzle velocities, the principal elements of horizontal trajectories, for differences in range of 100 meters (20 meters for most trench mortars). Intermediate values can be obtained by interpolation.

The elements given are generally:

The elevation.[2]

The maximum ordinate.[3]

The drift.

The angle of fall.

The time of flight.

The remaining velocity.[4]

The range, deflection, and height probable errors.[5]

The fork for use in range adjustment (par. 22).

The following additional elements are given for fuses which permit time fire:

The fuse setting for a 0 height of burst.

The angle of opening of the shrapnel (or half of this angle).[6]

---

[1] The trajectory is not changed, for example, if the 24/31 nondelay percussion detonating fuse, Model 1899, is substituted for the delay fuse, Model 1899–1908, or if the nondelay fuse, Model 1899–1915, is substituted for the short or long delay fuses, Model 1899–1915. Fuses of the same weight may be changed at will, if they are covered by a false ogive or a cap. The form will be changed if, for example, the 24/31 percussion detonating fuses, Model 1899, or instantaneous, Model 1914 or 1899–1915, are interchanged.

When the form is but little altered by changing the fuse, the effect on the trajectory will be slight, and the same firing tables will be applicable for practical purposes. Nevertheless, if a certain fuse is used to facilitate adjustment, and later changed, the subsequent fire must be carefully observed.

[2] Some tables issued by the French Navy give the angle of departure instead of the elevation. The latter can be calculated by means of the jump (par. 2).

[3] The French Navy tables generally give the range of the maximum ordinate also.

[4] Some tables also give the horizontal and vertical remaining velocity. If not, these values can be calculated (par. 7).

[5] Some tables do not give the height probable error, but it can be calculated (par. 22). The French Navy tables for high-power artillery generally give the mean error instead of the probable error. The probable error can be calculated from the mean error as explained in paragraph 19.

[6] The fuse setting in seconds may differ materially from the time of flight since the velocity of combustion of a fuse is a function of the muzzle velocity, the velocity of rotation, and the shape of the projectile.

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The range of burst and height of burst probable errors for time fire.

Some firing tables further give:

Information as to the displacement of the point of fall or burst for a given change in elevation or fuse setting.

For matériels having the laying instrument for elevation graduated in range, the range setting, when it is not the same as the range.

**32.** The elements corresponding to the same muzzle velocity, projectile, and fuse are given in a single table. All of the tables for a given piece are usually collected in a single volume. The firing tables, as a rule, also give miscellaneous useful information, such as:

Information in regard to the matériel, projectiles, fuses, charges and their use, muzzle velocity, etc.

Various tables intended to facilitate the preparation of fire (parallax, site, etc.).

General tables, giving for each range, the angles of fall which may be obtained. These tables permit a choice of the elements to be used when the defilade of the objective is known, as well as the other conditions affecting the success of the firing.

Tables for corrections made necessary by the fact that firing is generally conducted under conditions not tabular.

**33.** These last tables may be either in the form of **variations** in the trajectory due to the existence of conditions not tabular, or in the form of **corrections** to offset these variations. In using a firing table, it is important to note whether it gives **variations** or **corrections.**[1]

---

[1] When the tabular conditions are departed from a given elevation no longer gives the tabular range. For instance, if the tabular range is 7,000 meters, the range actually obtained may be only 6,640 meters. It is then said that there is a variation of −360 m. If the actual range were greater than the tabular the variation would be positive.

If, on the other hand, it is desired to obtain a range of 7,000 m., since variations are not materially changed for small range changes, a correction of +360 m. must be applied to 7,000 m., giving a corrected range of 7,360, for which the elevation must be sought in the firing tables. A variation and the corresponding correction are thus equal and opposite in sign.

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## CHAPTER 4.

## CORRECTIONS.

**34.** The causes of variations in the trajectory are of three kinds:

(*a*) **Topographic.**—The point of fall is in general not at the same level as the piece.

(*b*) **Atmospheric.**—In general, the weight of a liter of air is not exactly 1 g. 208 at the battery position. The projectile is affected by the wind.

(*c*) **Ballistic.**—The piece, even though new, is never exactly normal, and for this reason the muzzle velocity is not tabular (calibration error) (régime de pièce). The standard charge is established within certain tolerances. The quickness of the powder lot used may be other than that for which the charge was established, either due to tolerances in acceptance or to seasonal variations. The powder temperature may not be 15 degrees. The projectile is not necessarily of exactly the tabular weight. The fuses used may vary slightly from their type.

The corrections for percussion and for time fire will be taken up successively.

### CORRECTIONS IN PERCUSSION FIRE.

#### TOPOGRAPHIC.

**35. Site.**—The objective P is generally at a different altitude than the piece O. When the objective is elevated, the site is positive; when the objective is below the piece, the site is negative.

Let PP′ (fig. 15) be a perpendicular to the horizontal OH. OP′ is the range.

The firing tables give the elements of the trajectory, corresponding to this range, but the trajectory OMP′ would not be suitable, since it would fall short of the objective if the site were positive,



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and over it if the site were negative. If ONP is the trajectory through the objective, the discrepancy in range would be P′C.

The distance P′C is the amount by which the range OP′ must be increased (+site) or decreased (−site) to make the trajectory pass through the objective.

For a given range OP′, and two sites equal in amount but opposite in sign, the site corrections in range will not be the same absolute amount.

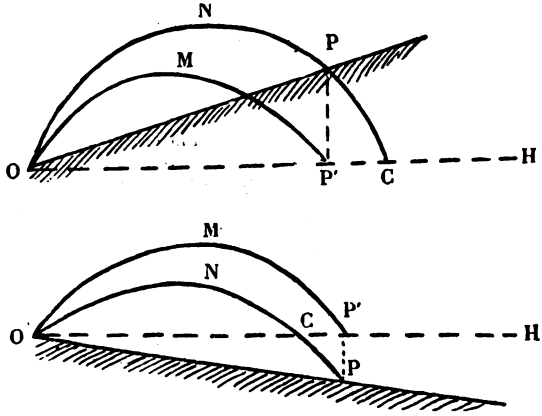


FIG. 15.

A double entry table may be constructed of the following form, having as arguments the difference in altitude between the piece and objective, and the map range. The values given are the site corrections in range [1] (fig. 16).

**36.** For high angle fire, giving angles of fall around 60 degrees, a method may be used which is merely a simplification of such a table.

[1] Such tables will be introduced in the new firing tables.

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The trajectory in this case may be taken as a straight line from the objective P to the point where it pierces the horizontal plane HH at C.

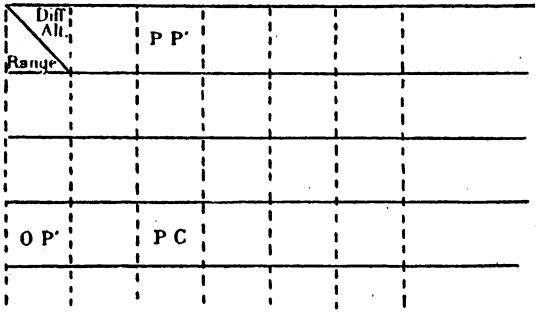


FIG. 16.

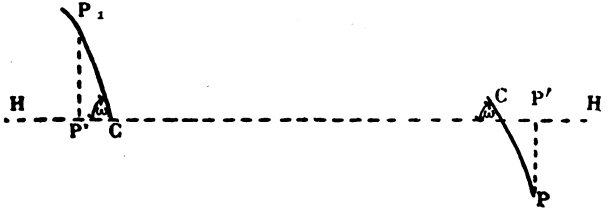


FIG. 17.

The site correction in range is then (fig. 17):

$$P'C=\frac{P\,P'}{\tan\,\omega}.$$

Where $\omega$ is the quadrant angle of fall.

For angles around 60 degrees, the tangent is approximately 2, so that:

$$P'C=1/2\ PP'.$$

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Hence the rule:

**In high angle fire, the map range should be corrected by one-half the difference in altitude PP′, additively if the site is + and subtractively if the site is −.**

**37. Complementary site correction.**—The present firing tables do not use the range correction for site, but apply the site to the elevation.

Let $a$ be the elevation for the map range OP′. Let $b$ be the quadrant elevation for the trajectory passing through the objective. Let $h$ be the elevation correction for a site, and $k$ for a − site.

Then $b=a+h$ (+ site).
or $b=a-k$ (−site).

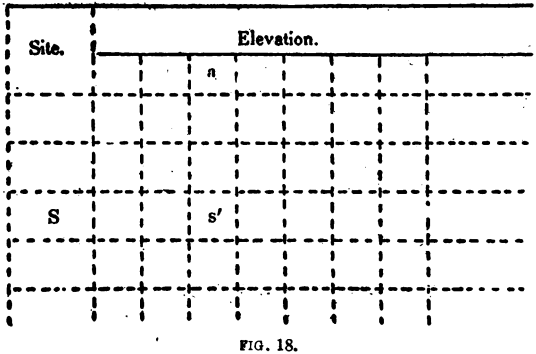


FIG. 18.

It is possible to calculate $h$ and $k$ by ballistics, and state them in the form of corrections to be applied to the site, S, which is the angle POP′. Then

$h=S+s'$
$k=S+s''$
$b=a+S+s'$ (+site)
$b=a-S-s''$ (−site)

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The angles $s'$ and $s''$ are called **complementary site corrections.**

The present tables have double-entry tables of complementary site corrections. The arguments are the elevation and the site. The form is shown herewith (fig. 18). There is one table for positive sites and one for negative sites.

**38. The rigidity of the trajectory.**—When the site is not great (less than 30′) and the elevations are not greater than say 20 degrees, complementary site corrections are small and may be neglected.

Then

$$b=a+S\ (+\text{site})$$
$$b=a-S\ (-\text{site})$$

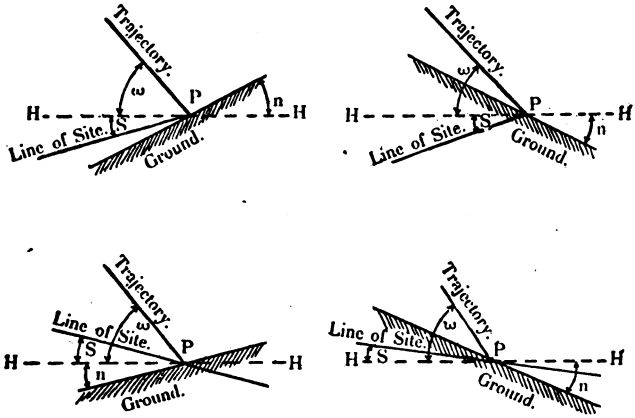


FIG. 19.

The slant range in this case is taken to be the same as the range. Under this assumption, the method virtually amounts to rotating the horizontal trajectory corresponding to the map range through an angle equal to the site.

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The assumption that the form and size of the horizontal trajectory are not changed when the trajectory is rotated through limited vertical angles is called the **principle of the rigidity of the trajectory.**[1]

**39.** In short, with the present tables, the site corrections are as follows:

Correct the tabular elevations for the map range by:

(*a*) The site, measured from the battle map or with a sitometer.

(*b*) The complementary site correction, taken from the firing tables.

These two corrections are both positive or both negative, according as the objective is above or below the battery.

**Maximum ordinate.**—Use the tabular value corresponding to the elevation corrected for site as just explained.

**Angle of impact,** or the angle between the tangent to the ground and the tangent to the trajectory at the point of fall.

Let

$\omega$ be the quadrant angle of fall;

S the site;

$n$ the slope of the ground at the point of fall, + for a forward slope and − for a reverse slope.

Then (fig. 19)

$$\text{Angle of impact} = \omega - S + n,$$

S and $n$ being taken with their proper signs.

**Other elements.**—The time of flight, fuse setting for 0 height of burst, drift, remaining velocity, and the probable errors are the tabular values for the range of the objective.

**40. Deflection correction for the inclination of the trunnions.**—When the trunnions are not level and the piece is elevated, the direction is changed toward the lower trunnion. It is therefore necessary to correct the deflection in the direction of the upper trunnion.

Let

$a$ be the quadrant elevation,

$i$ the inclination of the trunnions,

$c$ the deflection correction toward the high trunnion.

---

[1] The principle is not strictly accurate in any case, but it simplifies the laying of field artillery, without introducing serious errors. It is applied automatically in direct laying, that is, where the piece is laid entirely by sighting on the objective.

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Then

$$\tan c = \sin i \times \tan a.$$

Since the angles $c$ and $i$ are small, the equation may be written

$$c = i \times \tan a.$$

A double entry table, Appendix 3, gives the values of $c$ for the arguments $a$ and $i$. The values of $c$ are in mils.

**41. Remark.**—When the sight mounting can be cross leveled by rotation about an axis parallel to the bore, no correction of the deflection is necessary for the trunnions not being level. But in laying, the operation must be completed by a verification of the direction.

**42. Correction for the curvature and rotation of the earth.**—The tables for firing on land are constructed so that no correction for the curvature of the earth is necessary.

Corrections for the rotation of the earth are only necessary in using certain tables pertaining to long range matériel.

### ATMOSPHERIC.

**43. Air density.**—The greater the density of the air the greater its resistence to the projectile's flight.

The elements affecting the air density are:

Temperature.
Barometer.
Hygrometer.

The tabular air density is lg. 208 for the weight of a liter of air, at 15 degrees temperature, barometer 750 mm., and relative humidity 1/2.

When the weight of a liter of air is other than the tabular value, it is necessary to make a range correction. This correction is positive for weights greater than the tabular value, and negative for lesser weights.

The meteorological stations issue frequent bulletins giving the barometer and temperature for the mean altitude of the batteries (Appendix 4).

It is necessary to determine at the battery, for the conditions of the moment, the weight of a liter of air, $\pi$, from the chart in the firing table, and the difference $d\pi$ between it and the tabular value, which is

$$d\pi = \pi - 1.208.$$

This difference is expressed in milligrams.

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Because of the slight ballistic effect of the hygrometric state of the air, corrections for this element are in general neglected.[1]

The range variation for $d\pi$ is obtained from the firing tables.

Other atmospheric disturbances, such as fog, rain, and snow, increase the air resistance to an extent which varies considerably.

**44. Wind corrections.**—The meteorological stations furnish the **ballistic wind** for maximum ordinates differing by 500 meters (Appendix 5).

The ballistic wind is determined by:

(*a*) The direction from which the wind comes, measured clockwise in decagrades from the true north.

(*b*) The velocity in meters per second.

From the meteorological data in regard to the wind, determine the ballistic wind for the appropriate maximum ordinate by interpolation with respect to the two including values for which data are furnished.

Knowing the Y-azimuth of the wind, its direction with respect to the line of fire can be obtained from the battle map or by other convenient means.

With this latter value and the wind velocity, refer to the **wind rose,** or wind chart, in the firing tables, and take out the:

(*a*) Longitudinal wind component, or the wind velocity in the plane of fire.

(*b*) Lateral wind component, or the wind velocity perpendicular to the plane of fire.

By means of the firing tables, the variation or correction can be obtained for the range and deflection corresponding to the longitudinal and lateral components respectively.

## BALLISTIC.

**45. Weight of projectile.**—Increasing the weight of the projectile decreases the muzzle velocity and tends to decrease the range.

But for the heavier projectile the air resistance has less effect, which of itself tends to increase the range.

[1] For new tables, the tabular relative humidity is 3/4, which is nearer to average conditions than 1/2.

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The resultant of these two opposing tendencies in range depends on the weight of the projectile and on the range. For a given variation in the weight of the projectile, this resultant may change sign with a change in range.

The effect on the range of a variation in the weight of projectile, $dp$, is given in the firing tables for certain values of the variation. The effect for intermediate values may be obtained by interpolation.[1]

For the 75, the projectiles are sorted according to weight. The different categories are distinguished by different numbers of black crosses painted on the projectiles. The same correction is then applicable to all projectiles having a given number of crosses. The weight of each projectile of calibers greater than 75 mm. is marked on the projectile itself.

**46. Nature of the powder.[2] Standard charge.**—The different powder lots do not give the same muzzle velocity for the same charge (par. 29).

To minimize the difference between lots, the charge is established for each so as to give as nearly as possible the tabular velocity. The established charge for each lot is called the standard charge (charge d'emploi).[3]

In service, it can not in general be ascertained whether a new lot gives the tabular velocity.

It must be assumed at first that such is the case, and after adjustment, work backward from the adjusted data to find the amount by which the muzzle velocity departs from the tabular value (par. 286 and seq.).

**47. Temperature of the powder.**—Aside from the variation in muzzle velocity due to the quickness of the lot, just discussed, the

---

[1] Variations of muzzle velocity due to the weight of the projectile are greater for small muzzle velocities.

[2] The powders in use are classed in the following order of decreasing quickness: $BM$, BC, $BM_3$, BSP, $BM_3$, $US_3$, $BG_4$, $BG_5$, $BM_8$, BGC, $BM_7$, $BM_9$, $BM_{10}$, $BM_{11}$, $BM_{12}$, $BM_{15}$, $BM_{16}$, $BM_{17}$.

[3] The effect of a variation of the weight of the charge on the muzzle velocity may be approximately calculated by the expression,

$$\frac{dV_o}{V_o} = .7 \times \frac{d\pi}{\pi},$$

where the two ratios are the proportional variations in the muzzle velocity and charge respectively.

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muzzle velocity may not be tabular due to the temperature of the charges not being tabular. The greater the temperature, the greater is the muzzle velocity.

The variation in muzzle velocity due to the powder temperature may be approximately calculated by the following formula:

$$dV_o = k \times V_o \times dt$$

where $dV_o$ is the variation in muzzle velocity, $k$ a constant, $V_o$ the tabular muzzle velocity, and $dt$ the variation in temperature with respect to the tabular value of 15 degrees, $k$ is ordinarily .001.[1]

The firing tables give the range variation corresponding to $dV_o$.

**48. Wear of the gun.**—The wear of a gun reduces the muzzle velocity. The loss of muzzle velocity is a measure of the wear.

It has not been found possible up to the present time to determine the loss of muzzle velocity as a function of the number of rounds fired. Two pieces of the same caliber and fired the same number of rounds under the same conditions may show very different degrees of wear.[2]

The wear of a piece is determined with respect to a **reference piece,** by means of **calibration firing** (tir de régimage), conducted under the same conditions for both pieces (Appendix 13).

The difference between the adjusted ranges for two pieces, firing on the same objective, enables the differences in muzzle velocity to be determined from the firing tables.

Calibration firing is more important for the long range pieces, for which the wear is rapid and very variable for different pieces.

For the smaller calibers the wear is slower and the effects less serious. A satisfactory method for these calibers is to determine, by firing at several ranges and for several charges, the difference between the adjusted elevations for the piece to be calibrated and those for the reference piece. From the values thus obtained those for other ranges can be arrived at by interpolation or graphical methods.

### CORRECTIONS IN TIME FIRE.

**49.** In percussion fire the object is to cause the trajectory to pass through the objective. In time fire the burst must be placed in the proper position with respect to the objective (pars. 240 and 247).

[1] For the 75, $k$= .0006; for the 105, .0015. A purely empirical formula.

[2] Nevertheless it is of some advantage in predicting the loss of range, to establish a curve of wear for a given matériel.

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In general, the action of a time fuze is based on the combustion of a time train (except in the case of mechanical time fuzes). The causes which vary the trajectory (topographic, atmospheric, ballistic) also vary the position of the point of burst on the trajectory. The variations in the point of burst due to the existence of conditions other than tabular must be corrected for.

**50. Topographic.**—In paragraph 35 it is shown that the trajectory passing through an objective above or below the level of the piece differs slightly from the horizontal trajectory corresponding to the range of the objective. The trajectory corrected for site should, strictly speaking, be the one on which the calculation of the fuze setting should be based.

But in practice, when the site is small (say 1 degree), the initial fuze setting can be based directly on the range of the objective without serious error.

**51. Atmospheric and ballistic corrections.**—For firing against terrestrial objectives and balloons, these corrections are the same as for percussion firing, with an additional correction if necessary for the fuze setting.

The firing tables give corrected fuze settings corresponding to barometric conditions other than the tabular ones, due either to altitude or other causes.[1]

For matériels with fuze setters, these corrections are made with the corrector scale.

---

[1] The tabular barometric conditions are based on an altitude of 150 m. for most materiels and 1,500 m. for the mountain artillery.

Certain firing tables (145, Model 1910) contain charts for use in firing against balloons as follows:

(*a*) The correction in the fuze setting as a function of the range of the objective and the difference in altitude between the objective and the piece.

(*b*) The correction in the fuze setting corresponding to a variation in air density and to a given wind velocity.

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# PART II.

# RECONNAISSANCE.


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## RECONNAISSANCE.

**52. Object.**—Terrestrial reconnaissance is made by artillery commanders of all units. The objects are:

(*a*) The selection of positions for the artillery and its various units of information, observation, and command, together with the routes of approach.

(*b*) The organization and distribution of the work of installation.

On the care and skill with which the reconnaissance is made depends in a large measure the rapidity and success of the actual occupation of the position.

A complete and timely reconnaissance always saves considerable labor for the personnel in construction, and often prevents losses.

It is therefore very necessary to push forward a reconnaissance as soon as instructions are received looking toward the engagement of the artillery.



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## CHAPTER 1.

## SELECTION OF BATTERY POSITIONS.

**53. Object.**—The prime consideration is to enable the battery to fulfil its tactical mission. Provision must be made for delivering an effective fire on points whose position is defined by the direction, range, and site.

### GENERAL REMARKS.

**54.** The general location for the artillery is fixed by the higher command. Within this position, the various artillery commanders select the positions definitely, based on the following considerations:

(*a*) If the mission of the batteries is not definitely prescribed at the beginning, give them the greatest possible field of action.

(*b*) If the mission of the batteries is definitely prescribed from the beginning (the exceptional case), give them the greatest possible protection compatible with the fulfilment of this mission. Defilade them from terrestrial, and if possible, aerial observation.

(*c*) Facilitate liaison and command.

(*d*) Assure the ammunition supply and the installation of the personnel under the best possible conditions.

### TERRESTRIAL DEFILADE.

**55. Definitions.**—A battery is said to be **defiladed** from a given point when an observer at this point can not see the battery.

A battery may have terrestrial defilade, due either to a **covering mass** or a **mask.**

A covering mass shelters from view, and also affords a certain amount of protection. It is generally a fold in the ground whose summit is called a **crest.**

A mask simply affords shelter from view (hedge, line of trees, embankment, wall).

The **plane of defilade** is the plane from the point from which defilade is desired, to the summit of the covering mass or mask.

The **defilade of a battery** from a point is its distance below the plane of defilade.



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**56.** The defilade in meters is $d \times (S-S')$, where $d$ is the distance in kilometers from the position to the mask S the site in mils of the mask from the position, and S′ the site in mils of the point from which defilade is secured, seen from the summit of the mask[1].

**57. Firing from behind a mask.**—The battery position in rear of the mask must be such that the projectile, in firing on a given objective, will:

(*a*) Pass above the summit of the mask.

(*b*) Reach the objective without encountering intermediate obstacles.

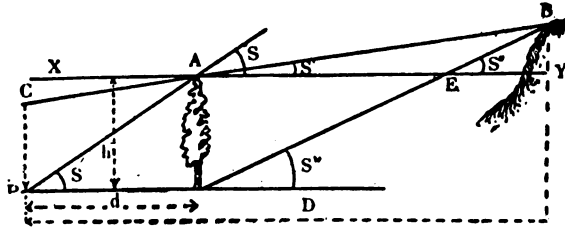


FIG. 20.

**58. Clearing the mask.**—Let T (fig. 21) be the elevation corresponding to the objective.

$t$ the elevation corresponding to the range of the mask.

S the site of the objective.

S′ the site of the mask.

---

[1] The defilade PC of the position P from B (fig. 20) is the product of the angle PAC in mils and the distance $d$ or $d \times (S-S')$.

When the summit of the mask is not accessible, S′ can be determined from the site S″ of B from the base of the mask, by the expression:

$$S' = S'' - \frac{h}{D-d}$$

where $h$ is the height of the mask in meters and D the range of the objective in kilometers. The derivation of this expression can be seen from the figure.

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The quadrant elevations corresponding respectively to the trajectories passing through the objective and the summit of the mask are:

$$T+S \text{ and } t+S'$$

The mask will be cleared when:

$$T+S>+S'$$

Which may be written

$$S'<T+S-$$

Whence the rule: [1]

The mask will be cleared when the site of the mask is less than the elevation for the objective **increased** algebraically by the site of the objective, and **decreased** by the elevation for the range of the mask.[2]

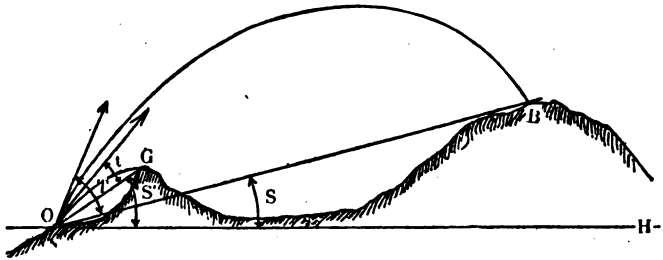


FIG. 21.

**59.** The terrain between the mask and the points of fall of trajectories just clearing the mask is called the **dead space.**

The limits of the dead space should be determined as soon as possible and marked on a battle map together with the horizontal

[1] Or the inequality may be written

$$T-t>S'-S$$

Whence the rule: The mask will be cleared when the difference between the site of the mask and the site of the objective is less than the difference between the elevation for the objective and the elevation for the mask.

[2] The principle of the rigidity of the trajectory is assumed (par. 38).

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field of fire. This information is called the **possibilities of fire** and should be furnished to the commander concerned.

**60. Remarks.**—For matériels having several charges, there is a different dead space for each charge. The same is true for the various projectiles, where the trajectories differ.

In calculating elevations, allowance should be made for dispersion in elevation and changes due to atmospheric conditions.

When the covering mass is a ridge, the rules for clearing the mask are in general satisfied by two positions, one close to the crest, called the **crest position,** the other at or back from the base of the ridge, called a **position of deep defilade.**

**61. To insure that the trajectory will encounter no intermediate obstacles.**—Determine from the battle map the range and altitude of intermediate obstacles in the plane of fire and compare them with the corresponding points of the trajectory.

In making this examination, particularly for obstacles close to friendly troops, increase the altitude of the obstacles by the height of trees and by six tabular height probable errors for the range used.

### FLASH DEFILADE.

**62.** Defilade of this character is involved only in the case of hostile balloon observation.[1]

It is ordinarily possible only for positions close to the mask [2], or in localities generally situated so as to afford deep defilade. It can sometimes be obtained by constructing an artificial mask a short distance in front of the battery.

Flash defilade is possible in general only for matériel firing at relatively high elevations. For flat trajectory pieces, the elevation is often less than that of the balloon, so that even an artificial mask can be only partial or lateral.

Lateral masks are useful in screening from the view of balloons placed obliquely to the front of the battery. This precaution should not be neglected, as experience has shown that adjustment by the combined observation of several balloons is dangerously accurate.

---

[1] Four meters is sufficient for the flash defilade of a 75 battery, 8 meters for smoke defilade.

[2] Positions close to the mask also require hostile aeroplanes to fly directly over the battery in order to adjust fire, which increases the difficulty of this operation.

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**63. Dust defilade.**—This is difficult to realize in most cases, but it is sometimes possible to select the position so as to have moist ground, pools, or water courses in front of the pieces.

### AERIAL DEFILADE.

**64.** Terrestrial defilade is relatively easy to obtain as compared with aerial defilade.

Aerial observation, and particularly aerial photographs, are the most successful means of discovering battery positions, due to:

(*a*) The smoke, flashes, and dust of firing.

(*b*) The characteristic aspect of battery emplacements, the blast marks on the ground in front of the pieces and paths and other evidences of occupation of the position.

(*c*) Indications afforded by the routes of supply.

The adjustment of fire on a battery by aerial observation is facilitated by the proximity of a prominent point, and if the emplacements stand out clearly with respect to the surrounding ground.

**65. Concealment.**—Batteries may escape detection by aerial observation and photographs by means of:

(*a*) The nature of the terrain and the natural cover it affords.

(*b*) Skillful construction of the emplacements and the approaches.

(*c*) Camouflage.[1]

(*d*) In certain cases, the use of smoke producers affording a momentary screen.

The first means is the best.

### RECONNAISSANCE OF POSITIONS.

**66. Defilade.**—First determine from just what points of the hostile positions the battery position is visible. This includes not only those immediately in front of the position, but those to the flanks as well. A casual examination of the map is not sufficient.

All such points should be carefully measured instrumentally, as with a declinated plane table or aiming circle.

The defilade of the position, and its approaches, from dangerous points of the hostile position and from balloons, is then determined (par. 55.)

---

[1] Camouflage must be used to conceal the construction. It is foolish to camouflage a battery position after it has been constructed in the open.

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In general, the security of a position increases with its defilade. Positions of deep defilade should be sought when consistent with the mission of the battery. In addition to the protection afforded, they are comparatively easy of access.

In some cases, deep defilade may be disadvantageous, as for example:

(*a*) Some positions, although well defiladed terrestrially, do not lend themselves to concealment from aeroplane observation.

(*b*) The amount of artillery to be emplaced may demand the use of all available positions.

(*c*) Low ground may have serious drawbacks, such as:

Gas clouds settling on it.

Dugouts not possible.

Apt to be subjected to systematic fire.

**67. Trench artillery.**—On account of its short range, trench artillery must often occupy positions without defilade. Such p sitions should be solidly constructed and not placed near prominent points.

**68. Places suitable for battery positions.**—(*a*) Woods generally afford excellent positions. The emplacements are difficult to discover and locate by aerial observation, the indications of occupancy are easily concealed, the adjustment of fire on them is very difficult, and materiel for construction is readily obtainable.

But projectiles bursting in a wood are generally more than ordinarily deadly. Positions at the edge of the woods are easily located accurately. The same is true of positions in a small clump of woods. Such positions facilitate the adjustment of fire.

(*b*) For similar reasons, the ruins of villages afford excellent positions. Concealment is facilitated, especially if the pieces are irregularly distributed. It is easy to avoid evidences of occupancy.

(*c*) Orchards are likewise suitable for pieces of small caliber.

(*d*) Infantry works also afford good positions for artillery of small and medium caliber. The construction may be effected without attracting attention.

The trench systems of defensive positions (2d and 3d lines) are favorable for emplacements. It is difficult to locate batteries so emplaced.

(*e*) Positions along roads are accessible and offer no evidence of occupancy; but if the road is much used the firing and ammunition supply may obstruct traffic.

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**69.** On open ground it is very difficult to conceal positions, especially on aeroplane photographs. This difficulty is enhanced if there are visible routes of supply, or evidences of occupancy. Under such conditions the dispositions should conform to the general lines of cultivation or other natural features. Proximity to prominent points should be avoided, since they would facilitate both the location of the battery originally and picking it up subsequently.

This precaution is particularly important in case the position is visible from hostile balloons, for adjustment by balloon observation is much hampered by the absence of a prominent point near the objective.

(See "The Organization and Construction of Battery Emplacements" for details of the construction of emplacements.)

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## CHAPTER 2.

## SELECTION OF OBSERVATION POSTS.

**70.** Artillery observation posts are of three kinds:
Intelligence observation posts.
Command observation posts.
Firing observation posts.
There are also auxiliary observation posts.

### INTELLIGENCE OBSERVATION POSTS.

**71.** These are the subject of special regulations.

### COMMAND OBSERVATION POSTS.

**72.** These posts are to keep commanders informed as to the situation and indications of hostile activity.

They should be situated on elevated points of the terrain, so as to afford an extended view of the sector and not merely of the zones of action of the batteries.

In order to facilitate observation of the terrain and to take advantage of information obtained, the battalion and group observation posts should constitute an **observation system** (réseau d'observation). The fields of view of the various posts should overlap. Such a system is particularly important for the heavy artillery.

### FIRING OBSERVATION POSTS.

**73. These posts must, above all, permit the objective to be seen, even in unfavorable weather. They should be close to the first line.**

In addition, they should if possible:
Have some command.
Afford easy communication with the battery (telephone and optical if possible).
Be close to the line of fire (par. 106).

**74. Heavy-gun batteries.**—For heavy guns (artillerie lourde longue), the radius of action of a battery is generally too extended to permit covering the entire battery zone from one observation post.

In this case, observation should be organized by battalions or groups (groupement). Suitable provision must be made for adjustment on datum and witness points.



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### AUXILIARY OBSERVATION POSTS.

**75.** In addition to the principal firing observation posts, each battery may make use of auxiliary observation posts, for certain points not clearly visible from the principal posts. If these posts are used in bilateral observation, a frequent case for heavy howitzers (artillerie lourde courte), their positions with respect to the line of fire should be taken into consideration (Appendix 8).

**76. Barrage batteries.**—Batteries charged with barrage fire should establish near the battery position a substitute observation post for use in case of hostile attack or failure of communication.

### RECONNAISSANCE OF OBSERVATION POSTS.

**77.** Elevated points are often used for observation posts, such as crests, trees, steeples, smoke stacks, etc. Underground posts are also used.

**78.** The observer must function however violent the action. Communications must be made as reliable as possible.

Permanent observation posts can be occupied by a considerable personnel of observers and telephone men. The construction involved is considerable,[1] and must be done very cautiously.

**79. Approach to observation posts.**—The observation post should, if possible, be near a defiladed road, giving easy access without exciting the suspicion of the enemy. The edges of woods and villages, and constructions of various kinds are advantageous in this respect, and in addition, afford elevation above the ground. Observation posts are revealed in aerial photographs by loose dirt, telephone lines, paths, and approaches, which end at the post. If the approach to a post is independent of a preexisting route (path or trench), the approach constructed must be prolonged past the post or camouflaged. This should be provided for in the reconnaissance.

**80.** As soon as the reconnaissance has been made, standing orders are issued governing circulation and restricting it as much as possible over the ground nearby, which is visible to the enemy.

These orders must be adhered to by all persons, regardless of rank.

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[1] Extreme care must be taken to conceal the work, utilizing both the natural cover afforded by the ground and camouflage. It is advantageous to use infantry works, mingling the dirt thrown up with that of works already identified by the enemy.

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## CHAPTER 3.

## SELECTION OF COMMAND POSTS AND RADIO STATIONS.

**81.** Artillery command posts must afford:

(*a*) A sure means of command.

(*b*) Constant touch with the situation.

(*c*) Ready liaison with the commander of the infantry which the artillery is to support.

**82.** Radio stations are close to their command posts in order to have:

(*a*) Prompt communication.

(*b*) A constant check on the firing by aerial observation.

**83. Command posts of higher artillery commanders.**—Division and corps artillery commanders should be near the division and corps commanders, respectively.

**84. Regiment and group command posts.**—These should be near roads. It is important to insure rapid and reliable communication by orderlies or cyclists, if possible, under all conditions with the divisional artillery, the heavy artillery, and the infantry to be supported, as well as with the battalions of the regiment or group.

It should be remembered that the low parts of the ground collect gas clouds.

It is well to conceal the circulation about command posts.

**85. Battalion command posts.**—Battalion command posts are chosen on the same considerations.

They should permit easy supervision of the personnel and work of the batteries.

It is desirable that the battalion commander be able to see his batteries, and at the same time be near an observation post.

**86. Battery command posts.**—Battery command posts are selected in the immediate vicinity of the battery.

**87.** The command posts of the different artillery units may be near each other, but they should never be in the same emplacement.



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# PART III.

# OBSERVATION.


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## CHAPTER 1.

## THE OBJECTS AND GENERAL PRINCIPLES OF OBSERVATION.

**88.** The objects of artillery observations are:
(*a*) To locate objectives.
(*b*) To observe and adjust artillery firing.
(*c*) To observe a zone.
Observation must be reliable and, as often as possible, continuous.
If the observer is inattentive or inexperienced, the artillery fires more or less at random, wastes ammunition, is poorly informed, and is not promptly responsive to calls made upon it.

**89.** The artillery has available for this service:
(*a*) Terrestrial observation posts.
(*b*) Balloons.
(*c*) Aero lanes.

**90. Characteristics of the different methods of observation.**—(*a*) Terrestrial observation is continuous, permits the use of precise measuring instruments, and is relatively independent of atmospheric conditions. But reliable terrestrial observation requires a long and careful study of the terrain, and involves an elaborate system of communications. The field of view is limited, and the deviation[1] of shots can but rarely be evaluated.

(*b*) The balloon permits continuous observation, and constant and reciprocal communication between the battery and the observer.
But the balloon has a limited field of view and the observing line is always oblique.

(*c*) The aeroplane affords rapid, accurate, and vertical observation on even the most distant and difficult objectives. But the observation is not continuous, and the communication between the aeroplane and the battery is generally not reciprocal.
Moreover, both balloon and aeroplane observation depend largely on atmospheric conditions.

[1] Distance from the objective.



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## CHAPTER 2.

## TERRESTRIAL OBSERVATION.

**91. Organization of terrestrial observation.**—Terrestrial observation consists of:

(*a*) **Intelligence observation posts.**—The organization and use of these observation posts is covered by the Intelligence Regulations.

(*b*) **Command observation posts** for artillery, pertaining to the different units, such as the battalion, regiment, group, division artillery, and corps artillery.

These observation posts afford each unit a general view of the zone assigned to the batteries of the unit. They should fulfill the general requirements stated in paragraph 72.

They may sometimes be used as firing observation posts, in which case they should fulfill the conditions of paragraph 73.

(*c*) **Firing observation posts** (observatoires de réglage) properly speaking, and sometimes auxiliary observation posts (postes d'observation auxiliaries). These observation posts pertain to batteries or battalions, depending on the circumstances.

**92.** Terrestrial observation for the artillery comprises:

(*a*) Preliminary topographical operations.

(*b*) Observation of fire.

(*c*) Observation of the zone.

### PRELIMINARY TOPOGRAPHICAL OBSERVATIONS.

**93. Determination of the coordinates of the observation post.**—This is done by topographical methods, using an angle measuring instrument (plane table, aiming circle, scissors telescope, periscope goniometer, etc.). If such instruments are not available, the observation post must be located as accurately as possible with respect to near-by points accurately shown on the battle map (see Appendix 11).

**94. Determination of an origin line** (direction origine).—An origin line is selected near the center of the sector of observation, to



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which angular measurements are referred [1]. Its Y-azimuth is determined by means of a declinated instrument, or one oriented on known points.

These various characteristics of the observation post are entered in the **observation post book** (carnet d'observatoire), and are plotted on the battle maps and firing board.

**95. Determination of datum** (but auxiliaire) **and witness points** (but témoin).—All points suitable for datum and witness points are located. They should conform to the conditions of paragraphs 292 and 299.

### OBSERVATION OF FIRE.

**96. Definitions.**—The **field of the observer** is the angle between the right and left limits of observation either with an instrument or the naked eye.

The **observing sector** (zone d'observation) is the sector subtended by the objective as viewed by the observer.

The **observing line** (ligne d'observation) is the line joining the observer and the adjusting point of the objective, or the point on which the fire is adjusted.

The **observer displacement** (angle d'observation) is the angle at the objective between the observer and the battery.

**97. Choice of an adjusting point** (point de réglage).—When the objective has been identified on the ground an adjusting point should be chosen. It must be clearly visible and should facilitate observation for range as much as possible.

**98.** The observer always refers the position of a shot to the observing line.

**99. Direction.**—The points of fall or burst are reported "right" or "left" by the observer as he sees them. The amount should be accurately measured by the observer with the instruments at his disposal.

**100. Range.—In the general case** shots are observable for range, or sensable, only when they are in the observing sector.

A burst is short or over according as it hides the objective or brings it into relief against the smoke.

---

[1] If the sector is very extended, several origin lines may be used.

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If the ground about the target slopes downward toward the observer, and if the point of fall is within the observing sector, the shot is short or over according as the point of fall is below or above the objective.

In the absence of smoke the dust and fragments thrown up by the projectile on striking may give information and should be carefully observed.

It is generally unsafe to consider a shot as short when the burst, though short, has a height greater than 1 mil (referred to the battery), for the trajectory may be over.

When the pattern on the ground of an air burst is entirely over, the trajectory is over, whatever the height of burst.

In general, the range deviation or burst interval of a shot can not be determined, even though the shot be sensed. In some cases, however, there may be points near the objective which can be identified and which are shown on the battle map. In this case such points afford a scale by which distances may be estimated.

After a shot falls the observer should promptly report it as "short," "over," or "doubtful." It is sometimes advantageous, however, to allow time for the smoke cloud to form, and possibly drift. But in doing this due consideration must be given to the possibility of the smoke drifting in the direction of range.

Observation must be very prompt in the case of H. E. shell of small caliber, as the black smoke available for observation is very fugitive.

Observation may be facilitated by a judicious selection of the fuse, taking into consideration the nature and condition of the ground.[1]

It is sometimes necessary, particularly when the bursting charge is small, to use **adjusting projectiles.**

**101. Height of burst.**—The height of burst with respect to the base of the objective or the covering crest should be carefully measured instrumentally by the observer.

---

[1] In general, the instantaneous fuse gives a ball of smoke which is easy for aeroplane observation.

The nondelay fuse gives an abundant but irregular cloud of smoke, which is suitable for terrestrial or balloon observation.

The short-delay fuse, bursting above the ground after ricochet, is not well suited to terrestrial observation if the objective is of low relief.

The long-delay fuse is unsuitable for observation, as it gives very little smoke.

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**102. Remarks.**—Unless the observer is himself conducting the fire, he simply reports the position of the shots in direction and height. The officer conducting [1] the fire converts these data into appropriate corrections to be applied at the battery.

The departure of the shots should be announced to the observer, in order that he may know when to expect the bursts and to enable him to report promptly in case a shot is lost.

### SPECIAL CASES OF OBSERVATION DUE TO THE RELATIVE POSITION OF THE OBSERVATION POST AND THE BATTERY.

**103. First case. The observer is on the line of fire.**—This is called **axial observation.**

(*a*) The observation post is approximately the same distance from the objective as the battery.

The deviation of a shot in deflection and height of burst can, in this case, be corrected without transformation for the position of the observer, at least when the shots are close to the objective in range.[2]

(*b*) The observation post is not at the same distance from the objective as the battery.

The deviation of a shot in deflection and height of burst as seen from the observation post must be transformed to the position of the battery by multiplying by the ratio of the distance of the observer from the objective to the range.

**104. Second case. The observer is not on the line of fire.**—If the observer displacement is less than 100 mils, observation is practically the same as in the preceding case.

If the observer displacement is greater than 100 mils, but less than 1,300 mils, the observation is called **lateral.**

The deviations as seen by the observer are different from those with respect to the battery in both range and deflection.

As seen by the observer, shots fired under the same conditions will be dispersed laterally due to a combination of the dispersion in

---

[1] **Conduct of fire** consists in employing the technical means necessary to cause fire of the desired nature to be brought to bear upon the objective.

**Fire direction** is the tactical command of one or more fire units with a view of bringing their fire to bear upon a suitable position upon the proper objective at the appropriate time.

[2] When the observation post is elevated with respect to the battery, the apparent height of burst will differ from the true height.

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range and deflection. The lateral dispersion increases with the observer displacement.

If the observer displacement is greater than 1,300 mils, the observation is said to be **flank.**

As seen by the observer, the lateral dispersion is due to the dispersion in range. Range adjustment is facilitated by the possibility of measuring range deviations, but deflection adjustment is more

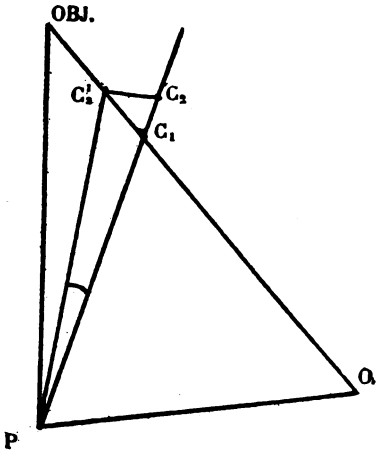


Fig. 22.

difficult because the range dispersion carries the shots out of the observing sector.

**105. Unilateral observation.**—Unilateral observation is the use of one observer in lateral observation (Appendix 7).

The initial firing data should be carefully determined. This is facilitated by using a place sketch (par. 170).

Fire should be begun with the initial data.



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The shots should then be brought on the observing line by changing one or the other of the elements of elevation and deflection.[1]

Let $C_1$ be the first shot which is observable, sensed short.

$C_1$ is plotted on the sketch, and the line $PC_1$ drawn through it. If an elevation change corresponding to one fork is made, without changing the deflection, the shot will fall at, say, $C_2$ and not be sensable. To bring $C_2$ on the observing line, the deflection must be changed by $C_1PC_2$, which can be measured from the sketch.

This deflection change is tried and corrected if necessary. The deflection change corresponding to a given range change is generally practically constant, and when once established, can be used for all subsequent range changes.

**106. Remarks.**—Lateral observation involves a considerable expenditure of ammunition. The expenditure increases with the observer displacement, as the dispersion in range reduces the number of sensable shots.

**Whenever possible, lateral observation should be supplemented by axial observation.** The latter will at least serve to abbreviate the deflection adjustment.

**Bilateral observation** can also be used (Appendix 8).

Lateral observation makes the formation of the sheaf difficult, because of the dispersion in range. For this reason, it is advantageous to adjust with groups of two shots at the same data.

### OBSERVATION OF THE ZONE.

**107. Study of hostile works.**—The hostile terrain and works visible from the observation post should be minutely and systematically studied with all available means, such as observing instruments, battle maps, and aeroplane photographs. Important points are located accurately with respect to the origin line (par. 94).

These points should be shown on a **panoramic sketch,** and entered on the observation post data book and on the battle map.

A map should be prepared so as to show the parts of the terrain which are visible and hidden (visibility sketch).

---

[1] Change the deflection when the observer displacement is between 100 and 300 mils. Change the elevation when the observer displacement is between 300 and 1,300 mils.

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**108.** An active and continuous observation is maintained at the observation post in order to:

Discover all details of the hostile terrain and works.

Follow changes in them. Such changes should be properly recorded.

Immediately report all objectives appearing in the field of the observer.

All indications of hostile activity, such as construction, movement, firing, etc., are carefully noted.

Such observations should be measured and entered, together with the date and hour, on an **observation sheet,** and plotted on the maps and sketches.

### OBSERVATION POST RECORD.

**109.** The sketches, maps, and records previously described are a part of the **observation post record,**[1] which is completed by the **standing orders** and **liaison system** (dossier de l'observatoire, consigne, schéma de liaisons).

The standing orders are issued by the commanding officer to whose unit the observation post pertains. These orders prescribe the service of the observation post and the measures to be taken to prevent its discovery by the enemy (pars. 79 and 80).

The liaison system prescribes to whom the information obtained shall be communicated, and the order of priority.

---

[1] Copies showing the position of the observation post, the routes of approach and circulation near it, the liaison system, visibility sketches, etc., are forwarded to the appropriate commander, who distributes this information to the units concerned.

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# PART IV.

## PREPARATION OF FIRE.


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## CHAPTER 1.

## OBJECT AND DEFINITIONS.

**110.** The object of the preparation of fire is to open fire under the most favorable possible conditions.

It consists of:

Preliminary topographical operations.

Establishment on the base line.

Determination of the initial elements of fire.

**111. Preliminary topographical operations** (chap. 2).—The object of these operations is to find the topographical elements necessary for the establishment on the base line and the determination of the initial elements of fire.

They are performed partly during the reconnaissance and completed after the position is occupied.

**112. Establishment on the base line** (chap. 3).—This operation is to facilitate and hasten laying for direction on the different objectives which may be subsequently assigned to the battery.

It is carried out for each battery immediately after the occupation of the position and the assignment of a sector.

A battery is said to be **on the base line** (en surveillance) when the plane of fire of a particular piece (generally the first), called the **base piece** (pièce directrice), is directed on a well-defined point taken as the **base point** (point de surveillance), and when the planes of fire of the pieces are parallel. The planes of fire of the various pieces, taken as a whole, are called the **sheaf** (faisceau).

The line joining the base piece and the base point is called the base line (direction de surveillance).

The base point is a point of the terrain or of the enemy works, and situated within the sector. It is generally shown on the map, and is generally invisible from the battery position. Sometimes it is visible from an observation post (observatoire), from which it is simply designated on the terrain without being laid out on the map.

One base point may be common to several batteries.



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A battery can have several base points, in which case they are designated as No. 1, No. 2, etc.

The base point may be the objective itself, if fire must be opened immediately, or if there be but one objective.

**113.** The battery being on the base line, when an objective is assigned, the initial elements of fire are determined, and the pieces laid for range and direction (chap. 5).

**114.** For both light and heavy artillery, it is very necessary that the preparation of fire be as accurate as possible. The battery emplacements are usually defiladed, and the objectives visible only from observation posts considerably separated from the battery. Sometimes the objectives are visible only from aeroplanes or balloons. It follows that fire can be prepared accurately only by means of a map giving exactly the location of the pieces, base points, and objectives.

**115.** When maps are not available, or are not satisfactory, fire must be prepared by improvised methods, depending on the circumstances and based on measurements taken from suitably chosen observation posts.

In such cases, the preparation of fire is by the same principles as ordinarily, but with some modifications, as given in Chapter 4.

**116. Definitions.**

**Battle map** (plan directeur).—A large scale map (1/20000, 1/10000, 1/5000), showing the enemy works, and, in some cases, our own.

**Plane table** (planchette topographique).—A board, with tripod, on which is mounted a squared sheet, or a battle map, used for topographical operations on the ground.

**Firing board** (planchette de tir).—A board on which is mounted a squared sheet, or a battle map, showing the **orienting line** (direction repère), the base piece, the objectives, the witness points (buts témoins) and observation posts, used in the accurate measurement of the map elements of fire.

**Triangulation system** (canevas d'ensemble).—A network of natural or artificial points or markers whose position is accurately known. It is used for the topographical operations incident to the preparation and observation of artillery fire.

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**Lambert north, or Y-line.**—The direction of the vertical lines of the map squares, from bottom to top (Lambert system of projection).

**Y-Azimuth of a line** (gîsement).—The horizontal angle which this line makes with the Lambert north, or Y-line, measured clockwise from the north, 0 to 6400 mils (or 4000 decigrades).

**117. Orientation and Declination of Topographical Instruments.**

**Plane table.**—The plane table is said to be **oriented** when the lines joining plotted points are parallel to the corresponding directions on the ground. The plane table is said to be **declinated** when the declinator is so set that, when the plane table is moved so as to bring the compass needle opposite its index, the plane table is oriented.

**Goniometer, or angle-measuring instrument.**—The goniometer is said to be **oriented** when the zero of its horizontal scale is on the Y-line.

An aiming circle is said to be declinated when the reading (**declination constant**) (division de déclination) is known which must be set off in order that, when the needle is brought opposite its index by the general motion, the instrument will be oriented.

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## CHAPTER 2.

## PRELIMINARY TOPOGRAPHICAL OPERATIONS—GENERAL REMARKS.

**118.** The preliminary topographical operations incident to the preparation of fire consist of:

(*a*) Operations by the battalion reconnaissance officer (officeier orienteur pour le groupe).

(*b*) Supplementary operations in each battery.

**119.** In general, the preliminary operations by the reconnaissance officer are:

(*a*) The establishment near each battery of an **orienting line** (direction-repère), which is a line materialized on the ground. Its Y-azimuth must be determined.

(*b*) The location horizontally and vertically of one or more **place marks** (repères de position) near each battery.

The reconnaissance officer performs these operations as soon as the battalion commander indicates the battery positions, without waiting for the battery commanders to select definitely the positions for the pieces (pars. 122 to 135).

**120.** The supplementary topographical operations are performed by each battery as soon as the position is occupied or the positions for the pieces fixed. They are:

(*a*) The location horizontally and vertically of the base piece (par. 134).

(*b*) The location of the other pieces with respect to the base piece, usually by the direction of the front of the battery, the distances between the pieces, and sometimes the differences in level of the pieces (par. 135).

**121.** If the battalion topographical operations are not completed in time, all of the operations necessary for the preparation of fire must be performed by the batteries themselves (par. 136).

Conversely, the reconnaissance officer may have to perform or verify the battery topographical operations.

The battalion commander apportions the topographical operations necessary between the reconnaissance officer and the battery commanders.



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## BATTALION TOPOGRAPHICAL OPERATIONS.

**122. Selection of the orienting line.**—The orienting line is an origin in laying the pieces for direction.

It should therefore be selected so that, from one or more points on it, the pieces of the battery will be visible and within calling distance.

Frequently it is best to have it parallel or slightly oblique to the front of the batteries. This is necessary when the pieces must be laid for direction individually, as when the batteries are in woods or casemates.

**123.** Whenever possible, the same orienting line should be used for all of the batteries of the battalion.

**124.** The orienting line must be clearly materialized on the ground (fig. 23).

Ordinarily it is staked out by several markers carefully aligned. The number of these should be such that from all points of the line which must be used, at least two markers can be seen in the same direction. Whenever possible, the line passes through a distant marker consisting of a natural object (tree, bush, spot on the ground), a construction (steeple, chimney), a stake or flag specially placed for this purpose, or even a fictitious point having a real appearance to an observer on the line (intersection of the profiles of two woods or portions of the terrain).

The other markers should be stakes solidly planted and tagged so as to be easily seen and recognized by the personnel of the battalion. These markers should be made in advance by each battalion and carried with the topographical instruments.

The necessary measures should be taken to prevent the markers from being disturbed.

Sometimes an orienting line is found clearly traced on the ground, such as a railroad, or canal bank.

**125. The determination of the orienting line.**—The orienting line is determined by drawing it accurately on the squared sheet or on the battle map, or by finding its Y-azimuth.

The determination is by one of the following methods:

**126. First. Use of declinated instrument.**—Set the instrument over any point of the orienting line, carefully avoiding masses of metal. It should not be nearer to the pieces than 50 meters. The helmet should not be worn.

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FIG. 23.



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Orient the instrument by means of the compass.

Sight on the orienting line.

If the goniometer is used, read the Y-azimuth of the sight taken.

If the plane table is used, draw the sight taken. The direction of this line is defined either by its Y-azimuth read with the protractor or by the measured coordinates of two points on it.

The method by using a declinated instrument is the most rapid. It is sufficiently accurate for light artillery and for heavy howitzers and mortars,[1] provided the instrument is declinated in the locality where it is used.

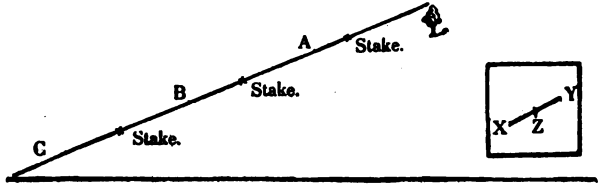


FIG. 24.

The first operation may be verified by setting up over a second point of the orienting line not less than 100 meters from the first point used. Take the first station to have been at A and *xy* the orienting line drawn on the plane table at this station (fig. 24). At the second station B, set any point *z* of *xy* over the station. With the plane table oriented, redraw the orienting line through *z*. The second line should coincide with the first. When using the goniometer, the two Y-azimuths read in this manner should agree within 2 or 3 mils, the mean being taken.

If there is disagreement between the lines drawn at the stations A and B, it is due to local variations in the compass needle. Repeat the operations (fig. 24) at other stations C, D, etc. When results are obtained which are in agreement, they will determine the orienting line.

[1] Plane table or aiming circle, 5 mils. Theodolite, 2 or 3 mils.

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**127. Second. When the orienting line is tied to an orienting point** (station d'orientation).—(*a*) If there is a point S, from which it is possible to orient accurately by means of distant known points and from which the battery position can be seen, the orienting line should pass through this point (fig. 25.)

Such a point as S is called an **orienting point.** By simply setting up over it and orienting the instrument the orienting line can be determined.

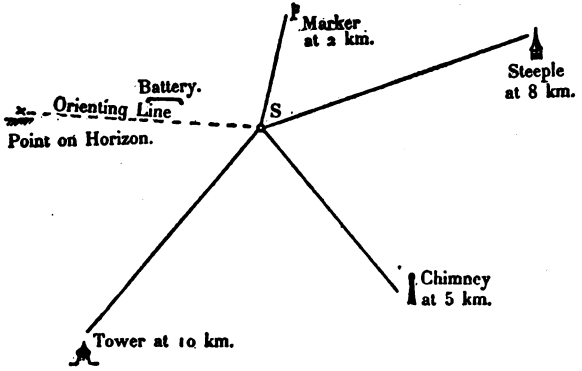


FIG. 25.

If the position of the battery can not be seen from an orienting point, but if it can be reached from this point by a traverse of a few courses, the method is as follows: Set up over S and determine first a line ST, which should be staked. Then go to any point U of this line (fig. 26), orient on the line ST (par. 466), and determine another line UV, which should also be staked. Continue in this way until a line is determined which can be used as an orienting line for the pieces.

In the use of the traversing method, stakes on which sights are taken must not be nearer than 100 meters, and the instrument must be set up on the line within 5 cm.

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The traversing method must not be used if the number of courses necessary is more than three for the plane table or aiming circle, or five for the theodolite. If the number of courses necessary exceeds these limits, it is better simply to transfer the orientation from S to the orienting line directly by means of the declinator.

**128. Third. Use of astronomical methods.**—For long-range firing, requiring great accuracy, the Y-azimuth of the orienting line may be determined astronomically, using the theodolite.

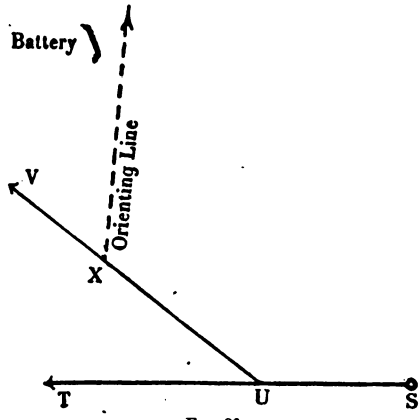


FIG. 26.

**129.—Fourth. Use of a distant marker.**—The orienting line may sometimes be directly determined from the known coordinates of two points on it, one, O, near the battery, which might be used also for the base piece, and the other, R, distant but visible from O.

The two points O and R are plotted on the plane table by their coordinates. The Y-azimuth can then be measured with a protractor. The Y-azimuth can also be calculated directly from the coordinates of O and R.

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In using this method, the distance OR should be of an order of magnitude comparable with firing ranges. The point R must be accurately known and O must be capable of accurate determination.

**130. Selection and location of place marks.**—The place marks located by the reconnaissance officer are to facilitate the location horizontally and vertically of the base pieces. They should be near the battery positions.

Sometimes a single place mark can be used for two near-by batteries.

**131.** Place marks are indicated by stakes so referred to near-by objects as to enable them to be reestablished in case they are disturbed. It is sometimes possible to use existing monuments, trees, or various other clearly defined objects whose permanency is assured.

**132. Determination of the coordinates of a place mark.**—This determination is based on near-by points of the triangulation system, or on details given on the battle map. As a rule, it should be made by a closed traverse. The three-point method (pars. 472 and 473) may also be used, verified, if possible, by a traverse.

**133.** The information and numerical data needed by the batteries in order to utilize the determinations of the reconnaissance officer in the preparation of fire are furnished to them individually, usually in the form of a sketch.

### BATTERY TOPOGRAPHICAL OPERATIONS.

**134. First case—Using data supplied by the reconnaissance officer.**—The base piece should be located horizontally and vertically by each battery, based on the nearest place mark located by the reconnaissance officer.

To avoid errors, the battery officer who does this should verify his work by means of near-by details given on the battle map.

**135.** When the base piece has been located, refer the other pieces to it by determining the length and direction of the lines joining them and the base piece. It is convenient to enter this data on a large scale sketch (such as 1/2000), properly oriented. Such a sketch is very necessary if the pieces are irregularly spaced.

If necessary, measure the difference in level between the pieces.

**136. Second case—No data supplied by the reconnaissance officer.**—In this case each battery must, by suitable topographical

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operations, determine the orienting line and locate the pieces horizontally and vertically.

**137.** To this end the battery officers proceed as described in paragraphs 118 to 133. But, since the instruments at their disposal are generally less accurate than those of reconnaissance officers, the methods used should be simple. If necessary, accuracy should be

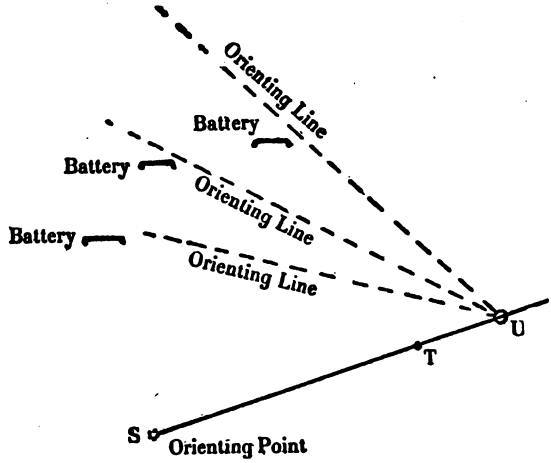


FIG. 27.

sacrificed to a certain extent in order surely to avoid any gross error.

**138.** For simplification, the orienting line for the battery may be taken through the base piece.

One of the points marking the orienting line is the sight of the base piece, which has the advantage of hastening subsequent operations (par. 150).

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This arrangement generally requires that the orienting line be determined by a topographical operation.[1]

Moreover, certain precautions must be observed in establishing the base piece on the base line (par. 150).

**139.** The location of the base piece horizontally and vertically should be based on details given on the battle map or the triangulation system. It should be verified by several other topographical operations.

**140.** When the battery determinations are not based on data supplied by the reconnaissance officer they should be checked against each other, in order to obtain the closest possible agreement in the preparation of fire for the battalion as a whole.

For example, if the orienting lines of the batteries are determined by means of a declinated instrument, the same instrument should be used for all batteries.

If they are tied directly to an orienting point in the vicinity, the same point should be used by all of the batteries of the battalion (fig. 27).

The base pieces of the different batteries of the battalion should be tied to each other.

---

[1] In general it is not possible to see from the positions of the pieces, markers fulfilling the double condition of being sufficiently distant and being accurately known (par. 129). Therefore an orienting line passing through the base piece can seldom be determined simply from the known coordinates of the base piece and a distant marker.

It is necessary, moreover, that the base piece be in position. It is not sufficient that its emplacement be selected and marked by a stake, since, as a rule, the piece can not be emplaced with sufficient accuracy to insure that the sight is accurately over the stake.



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## CHAPTER 3.

## ESTABLISHMENT ON THE BASE LINE.

### GENERAL REMARKS—DEFINITIONS.

**141.** The establishment on the base line consists of:

(*a*) Determining the base angle, or angle between the orienting line and the base line.

(*b*) Establishing the base piece on the base line.

(*c*) Establishing parallel fire.

The last two operations can be performed successively or simultaneously.

A battery with an extended field of fire sometimes uses several base points. The object of this is, in shifting fire, to avoid the errors incident to measuring large angles. Consequently, if a shift will carry the line of fire past a base point other than the one being used, the pieces should first be established on the new base line.

**142.** The **base angle** (angle de surveillance) is the horizontal angle between the base line and the orienting line, measured from the **base line** in the same direction as the sight graduations. In the figure, the base angle is $m$ mils for matériel with clockwise sights (75 and 155), and $d$ decigrades for counterclockwise sights (siege goniometer).

The **firing angle** (angle de direction) is the horizontal angle between the plane of fire and the plane of sight. It is measured from the plane of fire in the same direction as the sight graduations.[1]

It follows from these definitions that when the plane of sight is parallel to, or coincides with, the orienting line, and when the firing angle is equal to the base angle, the plane of fire is directed on the base point (fig. 29).

[1] The definitions of the base angle and the firing angle presuppose that the orienting line, base line, plane of sight, and plane of fire, are considered only in one sense and that the siege goniometer is used "au tonnerre" during the establishment on the base line.



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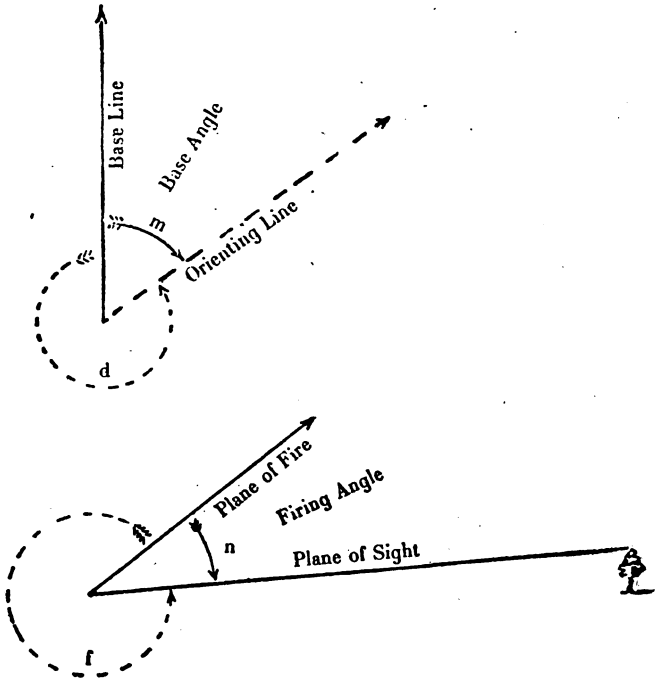


FIG. 28.

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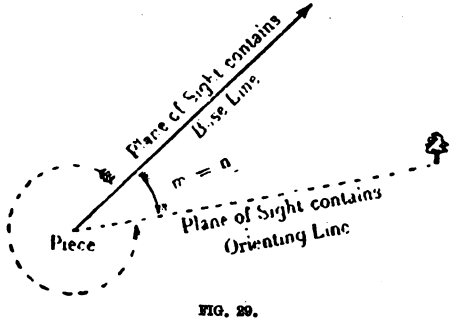


FIG. 29.

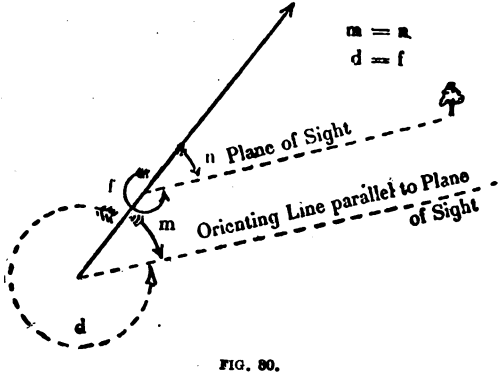


FIG. 30.

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The **deflection** (dérive) is the setting on the deflection scale of the sight.

The **deflection constant** (dérive normale) is the deflection for which the plane of fire and the plane of sight are parallel.

The deflection constant is about 0 for matériel equipped with the siege goniometer, 100 for the 75 gun, and 1,000 for the Schneider matériels.

To convert the firing angle into deflection:

Add the firing angle to the deflection constant.

If necessary, subtract a certain number of quadrants or a half-circle.

First example, siege goniometer:

| | |
|---|---|
| Firing angle | 1930 |
| Deflection constant | 2 |
| Deflection | 1932 |

Second example, 75 gun:

| | |
|---|---|
| Firing angle | 5025 |
| Deflection constant | 103 |
| Total | 5128 |
| Subtract 3 quadrants | 4800 |
| | 328 |

The deflection is Pl. 2 Dr. 128.

Third example, 155 Schneider Howitzer:

| | |
|---|---|
| Firing angle | 5025 |
| Deflection constant | 998 |
| Total | 6023 |
| Subtract a half-circle | 3200 |
| Deflection | 2823 |

### DETERMINATION OF THE BASE ANGLE.

**143.** Plot the base point and the base piece on the firing board, by means of their coordinates.

Draw the base line by joining these two points.

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Plot the orienting line with the protractor, if it has been determined by its Y-azimuth, by means of the map squares if it has been determined topographically with the plane table.

Measure the base angle from the base line in the same direction as the sight graduation.

### ESTABLISHING THE BASE PIECE ON THE BASE LINE.

**144.** If the orienting line does not pass through the sight of the base piece, use a goniometer or plane table as a **director** (instrument directeur), established on the base line (par. 147).

If the orienting line passes through the sight of the base piece, the orienting line is used directly in laying for direction.

If the orienting line has not been previously established and determined, the base piece is established on the base line by means of a declinated instrument.

**145. First case.**—The orienting line does **not** pass through the sight of the base piece.

Either the goniometer (aiming circle, theodolite, scissors telescope, observation telescope) or the plane table can be used.

**146. Using a goniometer.**—Establish the instrument on the base line, that is, point its 0 in a direction parallel to the base line.

Then lay the base piece parallel to the 0 of the director by reciprocal laying, taking into consideration the deflection constant.[1]

**147. To establish the director on the base line.**—Set the director over the orienting line (within, at the most, a few centimeters), at a point from which the sight of the base piece can be seen.

If the graduations of the director and the sight are in the same direction, set the director at the base angle.

If the graduations of the director are in the opposite direction to those of the sight, set the director at 6,400 (or 4,000) **less** the base angle.

Using the general motion, point the director on the orienting line. The 0 of the director is then on a line parallel to the base line.

---

[1] The base piece must be established on the base line only after the piece is in position. The method of marking the position for the sight by a stake, and measuring the deflection with a goniometer set over this point, before the arrival of the piece, must not be used.

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**148. The director being established on the base line, to establish the base piece on the same line.**—Lay the piece approximately for direction.

With the upper motion, that is, without touching the general motion, point the director at the sight column of the base piece. Let A be the reading of the directors so pointed.

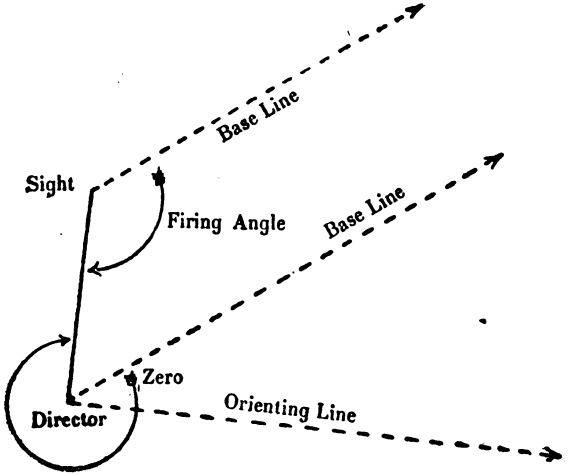


FIG. 31.

If the sight and director are graduated in the same direction, the firing angle to be given the piece is:

A+3,200 mils,[1] if A is less than 3,200 mils.

A−3,200 mils,[2] if A is greater than 3,200 mils.[3]

---

[1] Or A+2,000 decigrades.

[2] Or A−2,000 decigrades.

[3] The firing angle is in all cases A+3,200 mils, but if this sum is greater than 6,400 mils, it is necessary to subtract 6,400, which is equivalent to A−3,200 mils.

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If the sight and director are graduated in opposite directions, the firing angle is:

3,200 mils − A[1], if A is less than 3,200 mils.

9,600 mils − A[2], if A is greater than 3,200 mils.

The director and sight are graduated in the same direction (clockwise) (fig. 31). The angle A is greater than 3,200. The firing angle is A − 3,200.

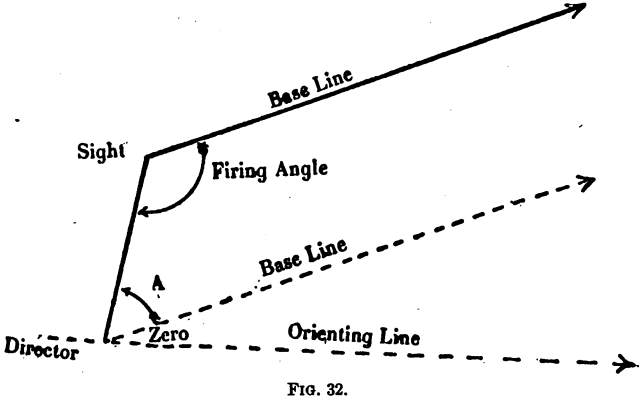


FIG. 32.

The sight is graduated clockwise and the director counterclockwise (fig. 32). The angle A is less than 3,200. The firing angle is 3,200 − A.

Having determined the firing angle, convert it into deflection (par. 142).

With this deflection, use the director as an aiming point.

Repeat this operation once or twice, on account of possible movements of the sight during laying.

---

[1] Or 2,000 − A decigrades.

[2] Or 6,000 − A decigrades.

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Refer [1] (repérer) the piece.

Record the deflection (base deflection.)

**Remark.**—In the case of the aiming circle for the 75, the angle A, when read on the special graduation, gives the deflection directly, without conversion.

**149. Using the plane table.**—The orienting and base lines should be drawn the full length of the plane table.

Set up the plane table over the orienting line.

Orient it by sighting on a distant point of the orienting line. This must be carefully done so that the orienting line on the plane table will be parallel to the same line on the ground, and over it to within a few centimeters.

With the slope rule alidade (alidade nivelatrice) or telescope alidade (règle à éclimètre), point on the sight column of the base piece.

Draw this line (V) the full length of the rule.

With the protractor measure the angle between the base line and the line V, from the base line in the same direction as the sight graduations.

This is the firing angle, which is then converted into deflection.

With this deflection, lay the piece for direction, using as an aiming point a pencil held vertically at any point of the line V.

Repeat this operation until the sight no longer moves in laying the piece.

Refer the piece.

Record the base deflection.

**150. Second Case—The orienting line passes through the sight of the base piece.**

The plane of sight is taken coincident with the orienting line, and the firing angle becomes the same as the base angle (par. 142). The firing angle can then be determined as described in paragraph 143.

Convert the firing angle into deflection.

---

[1] "Refer" means to take an auxiliary or individual aiming point, called the **referring point,** by directing the sight on this point without disturbing the laying. When the piece is referred to a distant point, the following method may be substituted: Establish the base piece approximately on the base line. Refer it first to the distant point and then to the director set up and established as described in paragraph 152. From this second reference, the deflection change necessary to establish the piece on the base line can be deduced, and the piece laid for direction in one operation, using the distant referrring point.

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Lay for direction with this deflection, using the orienting line as an aiming point.

Refer the piece.

Record the base deflection.

When the marker of the orienting line, which is used as an aiming point, is close, care must be used to insure that the base piece is not thrown off the orienting line while laying for direction. To this end, it is well to establish a supplementary marker on the orienting line near the piece.

**151. Third case.—Without preliminary determination of the orienting line.**

In this case, the **magnetic north** is used as an orienting line. The director is any declinated instrument, aiming circle, compass theodolite, plane table.

The instrument used must be previously declinated and set up at least 50 meters from the piece.

**152. Using a declinated aiming circle.**—The method is analogous to that described in paragraphs 146, 147, and 148. The aiming circle is established on the base line. The base angle is the angle between the base line and the magnetic north. Let L be the declination constant (par. 117), and V the Y-azimuth of the base line, measured on the plane table or calculated. The base angle is then L−V.[1]

Set the aiming circle at the value of the base angle. Then, with the general motion, bring the needle opposite its index. This operation establishes the aiming circle on the base line (par. 146).[2]

The aiming circle being established on the base line, the piece is so established, as described in paragraph 148.

**Remark.**—This result should be verified by a similar operation at a point about 100 meters from the first, to eliminate local attraction. The two deflections thus obtained should not differ by more than 2 mils.

---

[1] Or 6,400+L−V, if L is less than V.

[2] When the aiming circle is oriented (par. 117), the scale is so placed that if the telescope be pointed at the Lambert north, the reading will be 0 (6,400). If the compass needle is brought opposite its index with the upper motion, the reading will be say L=6,180 (fig. 33).

Let IS be parallel to the base line, the azimuth of which is say V=864. In order that, when the instrument is pointed in the direction IS, the reading be 0 (6,400) the scale must be turned clockwise 864 mils. When the needle is brought opposite its index with the upper motion, the reading will be 6,180−864=5,316, or in general L−V.

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**153. Using the plane table.**—Orient the plane table by means of the declinator, and continue as described in pargraph 149.

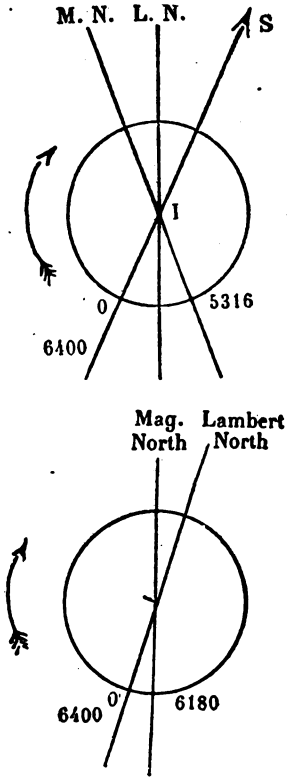


FIG. 33.

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## ESTABLISHMENT OF PARALLEL FIRE.

**154.** Parallel fire may be established by:

First. Establishing each piece on the base line by means of the director.

Second. Use of a common aiming point.

Third. Reciprocal laying on the base piece.

**155. Parallel fire, using the director.**—It is best to use a director established on the base line by means of the orienting line. The director should be used if possible from one point for all pieces, on account of both rapidity and accuracy. When conditions make this impossible (woods, casemates), and several positions of the director are necessary, use particular care in setting the instrument accurately over the orienting line.

A declinated director should only be used when the pieces can be established on the base line from a single point. Its use from more than one point should be resorted to only when all other methods are impracticable.

It should be remembered that the establishment of a battery on the base line depends only on the orienting line and the base line (as marked by the base piece). The operation is independent of the position of the other pieces and the director.

**156. Parallel fire by using a common aiming point.**—The aiming point may be either:

The marker on the orienting line used as an aiming point by the base piece in establishing itself on the base line, when the orienting line passes through the sight of the base piece.

Any aiming point to which the base piece may be referred after establishment on the base line, or which may be used in this establishment (footnote, page 92).

All pieces use the common aiming point.

The deflection of a given piece is that of the base piece corrected for the parallax of the aiming point for the front base piece—given piece.

If the pieces are on line and equally spaced, the deflection difference is constant. This deflection difference is the parallax of the aiming point for the front of the battery, divided by one less than the number of pieces, that is, the number of intervals between the pieces.

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**157.** The sign of the deflection difference depends on the position of the aiming point (front or rear), and on the direction of graduation of the sights.

To avoid mistakes in the sign of the deflection difference, remember that a 0 deflection difference gives an **open** sheaf with a **rear** aiming point, and a **converged** sheaf with a **front** aiming point.

The deflection difference for parallel fire must then close the sheaf if the aiming point is in rear, and open it if the aiming point is in front.

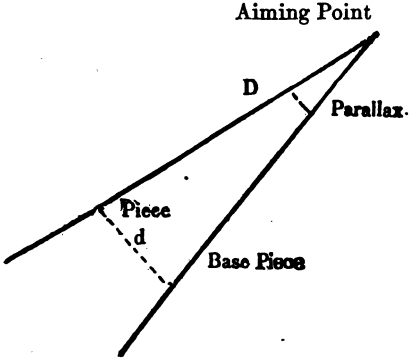


FIG. 34.

**158.** The methods of determining the parallax are:

Calculation.

Measurement on the map.

Measurement on the ground.

**159. Calculation of the parallax.**—Let *d* be the distance in meters from a given piece to the plane of sight of the base piece.

Let D be the distance in kilometers from the battery to the aiming point (fig. 34).

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Then the parallax is:

In mils: $\frac{d}{D}$.

In decigrades: $\frac{d}{1.57 \times D}$, or approximately $\frac{d}{1.5 \times D}$, $d$ is measured perpendicular to the plane of sight, either by pacing, or by measurement on the large scale map (par. 135), if one has been made.

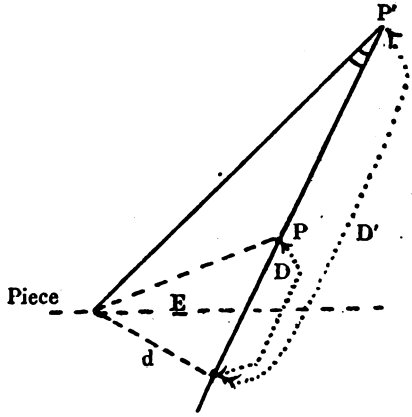


FIG. 35.

The range D is measured on the map, or, if there is no other means, estimated.

When $d$ is paced and counted in strides of about 1.5 mils, and $n$ is the number of strides or double paces, the following formulas give the parallax directly:

Mils: $1.5 \frac{n}{D}$.

Decigrades: $\frac{n}{D}$.

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## REMARKS ON THE VARIATION OF THE PARALLAX.

Let E be the interval between a given piece and the base piece, and P the aiming point:

(*a*) As the aiming point recedes along the line base piece—aiming point, the parallax decreases (fig. 35).

(*b*) As the aiming point moves to the flank, but remains at the

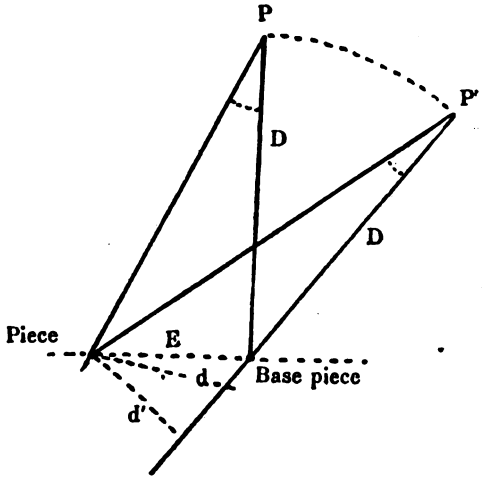


FIG. 36.

same distance from the base piece, the parallax decreases (fig. 36).

(*c*) As the aiming point both moves to the flank and recedes from the base piece, the parallax decreases the more rapidly.

(*d*) The parallax remains constant if the aiming point moves to the flank, but remains on the circumference through the aiming point and tangent to the battery front (fig. 37).

(*e*) The parallax is 0 when the aiming point is on the flank.

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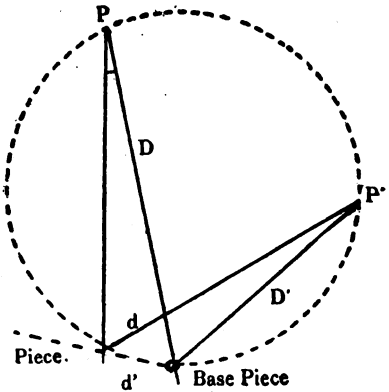


FIG. 37.

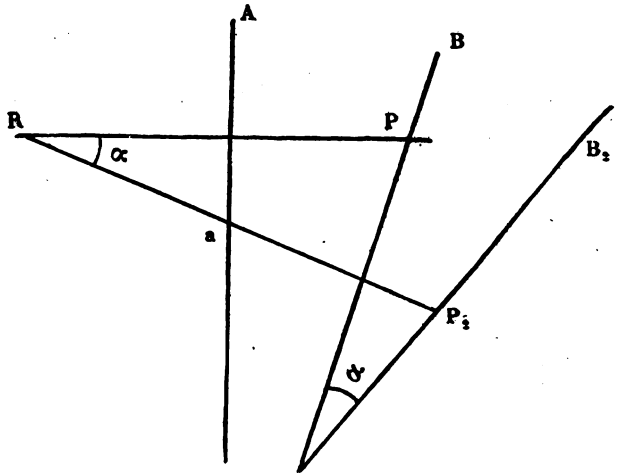


FIG. 38.

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**160. Measurement of the parallax on the map.**—This method is especially appropriate when the pieces are irregularly spaced.

Use a large scale map or diagram of the battery and the parallax protractor (appendix 12. Use of the parallax protractor).

**161. Measurement of the parallax on the ground.**—This is the best method when the aiming point is close.

Set up a goniometer at the aiming point itself and measure the parallax directly.

**162. Parallel fire by reciprocal laying on the base piece.**—This method is described in the drill regulations.

It is the least satisfactory of all.

**163. Referring—Recording the base deflections.**—The battery being on the base line, each piece is referred, either to a mirror or a referring point (point de repérage), which is used during firing. In the latter case, take two referring points, one distant for use in the daytime and the other close for use at night. The distance of the night referring point should not be less than 150 meters.[1]

---

[1] In batteries not equipped with mirrors (recent matériel) very near referring points are sometimes necessary.

Under these conditions, when the sight is displaced, errors in direction as great as 5 mils or more may occur. This may be corrected in the following manner (fig. 38):

Let R be a referring point close to the sight P. The piece is laid in the direction PB. A graduated rule is placed at A perpendicular to PR, with its 0 on PR, at a distance such that its graduations will be in mils from R. If the sight is displaced to $P_2$ and the piece relaid, it will be in the direction $P_2 B_2$. An error in laying thus results which is equal to $\alpha$. The gunner reads this angle directly on the rule from the position of the sight, and himself makes an appropriate deflection correction.

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## CHAPTER 4.

### PREPARATION OF FIRE WITHOUT A MAP.

**164.** When the topographical preparation of fire is effected without maps, it is necessary to resort to improvised methods based on the base points and objectives being directly visible.

**165.** In open warfare, or in position warfare for the pieces assigned to close defense, the objectives may be visible from the battery positions or from points nearby. This is particularly true for light artillery. In such cases the objectives are usually mobile or fleeting. Fire must be opened as rapidly as possible. Direct laying is used for direction, or if this is not possible, reciprocal laying, using a director (aiming circle—observation telescope) established on the objective. The range is estimated or preferably measured by range finder.

In this case the preparation of fire is practically immediate.

**166.** But generally the base points and objectives are visible only from observation posts separated from the batteries. Moreover, the fire should be carefully prepared, so as to enable fire to be opened under favorable conditions on any objective, fixed or mobile, which may appear in the sector.

The principles used in the preparation of fire under these conditions are the same as for firing from the map.

By preliminary topographical operations, the relative positions of the observation post, base point, and base piece are plotted on a firing board. The orienting line is determined with respect to the plotted points. The base angle can then be measured with the protractor.

The establishment of the battery on the base line is then accomplished by the usual methods.

**167.** An observation post is first chosen, from which the objectives and base point are visible. The orienting line is taken through this observation post and the immediate vicinity of the battery. From the observation post angles are measured with respect to the orienting line and distances are measured or estimated, which will fix the relative positions of the battery, base point, and objectives.

**168.** If the battery position is visible from the observation post, the orienting line is staked from the observation post to the base piece or its vicinity.



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When the plane table is used (fig. 39), draw through the point O, representing the observation post, a line OS to the base point, a line OP to base piece, and the orienting line if it differs from OP.

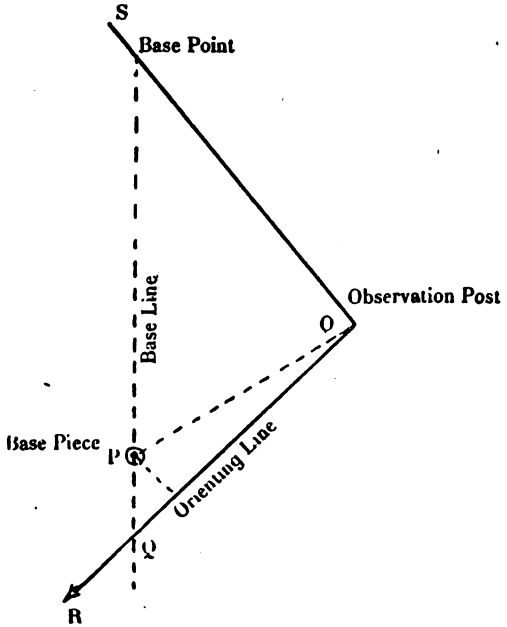


FIG. 39.

Locate the piece P by measuring its distance from the observation post, verifying if necessary by measuring its distance from the orienting line.[1]

[1] Measure O P by range finder, for example, and the distance of P from the orienting line by pacing. The difference in level between the piece and the observation post should also be determined.

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Join S and P, and measure the base angle SQO on the plane table, in the appropriate direction (par. 142).

If a goniometer is used, measure at O the angles SOP, and if necessary SOR. Plot them and proceed as just described.

**169.** If the battery position is not visible from the observation post, the orienting line can not be taken through the observation post. It must in this case be established near the battery independently of the observation post.

For the topographical operations, use a declinated plane table or aiming circle.

**Declinated plane table.**—Set up at the observation post and orient with the declinator. Take any point as O (fig. 40), and locate the base point S by its direction and distance. Locate the base piece by a traverse from O. Join P and S. Set up on the orienting line and draw its direction on the plane table. With the protractor measure the base angle SQR.

**Declinated aiming circle.**—Use the same method. The orienting line and the line OS are determined by their measured Y-azimuths.

After the necessary graphical construction, measure the base angle with the protractor.

**170.** If fire is not opened immediately after the establishment on the base line, continue the preparation of fire by locating probable objectives, and prominent points on the terrain which will facilitate the location of objectives appearing later.

This is accomplished by the measurement of angles, sites, and distances from the observation post with the usual instruments, and plotting them on a **place sketch** (croquis planimétrique) (par. 182).

The place sketch (generally 1/20000) shows the positions of the battery, the observation post, the base points, and the objectives.

**171.** When the batteries of the battalion are together, the operations pertaining to the preparation of fire are performed with respect to the battalion commander's observation post and the topographical registration of the terrain is organized by the battalion commander.

In this case, it is sometimes necessary, on account of lack of time or for other reasons, to abbreviate the preparation of fire. This entails a testing fire (tir de vérification) (par. 203), which should be

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by a single battery. The corrections found necessary in the base elements are applied to all batteries of the battalion.

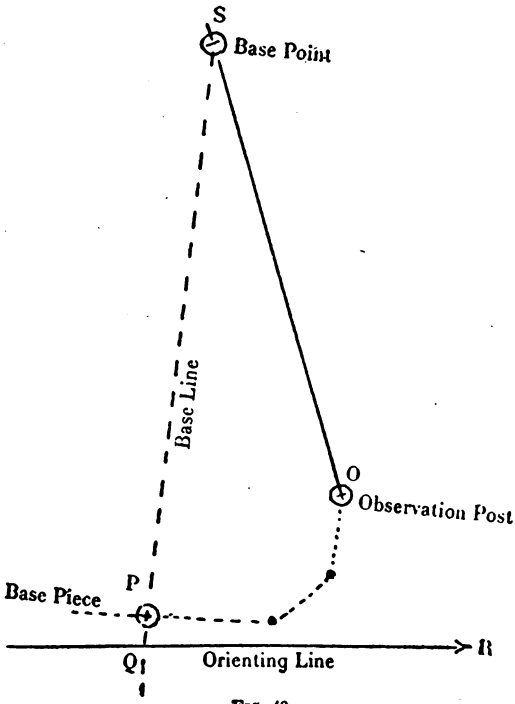


FIG. 40.

**172.** When time is available, neighboring battalions should tie together the topographical operations effected by each in the preparation of fire, particularly those pertaining to the location of observation posts and objectives.

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## CHAPTER 5.

## INITIAL FIRING DATA.

### GENERAL REMARKS.

**173. The initial preparation of fire** on a given objective consists of:

(*a*) Measurement of the **topographical characteristics** of the objective:

Angular distance from the base point.

Front and depth.[1]

Range and site.

(*b*) Study of **firing conditions:**

Kind of fire (percussion or time).

Projectile and fuse.

Charge.

Angle of impact suitable for the objective.

Method of fire for effect.

Method of observation.

Method of adjustment.

(*c*) **Determination of initial firing data:**

**Deflection.**—The change in deflection and deflection difference to be given to the battery on the base line in order to shift and distribute the fire on the objective.

**Range.**—The elevation or range setting.

**Height of burst.**—The fuse setting or the corrector.

**174.** The determination of the initial firing data involves:

First. The map data in regard to the objective.

Second. The ballistic data of the firing tables.

Third. The conditions of the moment, such as meteorological data and the characteristics of the powder lots and projectiles used.

---

[1] Examine also the terrain near the objective.



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**175.** Since it involves the conditions of the moment, the determination of the initial data can only be completed just before opening fire.

But everything possible should be done beforehand. Determination of map data for all probable objectives, study of firing conditions, and determination of such of the initial data as does not involve the conditions of the moment.

**176. The resumption of a previously adjusted fire** is based on the data of the first adjustment, **stripped** (dépouillé) of the conditions of the moment, as far as known, that is, corrected to the normal conditions of the firing tables.

### MAP DATA PERTAINING TO THE OBJECTIVE.

**177.** These may be measured:

From the firing board and battle map.

From the battle map alone.

Directly on the ground, when the preparation of fire is without a battle map.

**178. Use of the firing board and battle map.**—Measure on the battle map the coordinates of the adjusting point A of the objective, on which the base piece is to be adjusted.

Determine the altitude of this point.

Measure the slope of the ground about the objective. This slope is taken in the direction of fire and is:

**Positive** (plus) if the ground slopes upward away from the battery (forward slope or counter slope ).[1]

**Negative** (minus) if the ground slopes downward away from the battery (reverse slope).

Measure:

The front of the objective perpendicular to the direction of fire.

The depth of the objective parallel to the direction of fire.[2]

**179.** Plot A on the firing board and measure its map range from the base piece.

Measure the angle at the base piece between the base point and A.

[1] A counter slope is one sloping upward away from the battery, but distinct from and hidden by the ridge of the forward and reverse slopes.

[2] For precision fire, also note if necessary the echelonment of the objective in depth and the difference in level of parts of the objective with respect to the point A.

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**180.** Calculate the site of A for the base piece by means of the range and the difference in altitude between the objective and the base piece, H′—H.[1]

**181. Use of the battle map alone.**—The map data may be measured directly from a 1/20000 battle map (generally mounted on a board), or from a 1/50000 map when the base piece has been accurately plotted on it. In such a case, all of the measurements are made, as just explained.

It is also possible to use a map showing only the **objective zone** (zone des objectifs). This map, called the **objective map** (plan d'objectif), is generally to a large scale (1/5000 of 1/10000). This is a convenient method of preparing fire for a large number of objectives on the same sheet of the map.

The objective map must have angular graduations centered on the base piece and showing the base line. There should also be range circles, centered on the base piece, for each kilometer.[2]

On this map, angular distances can be read directly and ranges scaled from the kilometer circles.

The other measurements and determinations are made as previously.

**182. Determination of map data on the ground without a battle map.**—Use the place sketch (par. 170), made from the observation post.

Measure the angular distance and range from this sketch.

To calculate the site, convert the site measured at the observation post into the difference in level between the observation post and the objective. From this, find the difference in level between the battery and objective, and compute the site.

---

[1] In high angle fire, the site is not calculated. Instead, the map range is algebraically increased by one-half the difference in altitude $\frac{H'-H}{2}$ (par. 36).

[2] The base line and range circles are first drawn on a 1/20000 battle map, which includes the battery and the base point. The necessary portions of these lines are then transferred to the objective map by means of the map squares. For long-range firing requiring great accuracy, use calculation.

To make the angular graduations, use the parallax protractor on white paper (see Appendix 12). Place the map on the protractor, with the base line coincident with the protractor axis. Slide the map along this axis until it is in the proper position as regards range, which can be ascertained by the scale. Fix the map in position and draw in the graduations on the map from those on the protractor.

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The slope of the ground near the objective and the depth of the objective are estimated.

**183. If the place sketch is not available.**—The angular distance of the base point from the objective, measured at the observation post O (fig. 41), is converted to that at the base piece P by a **station correction** (correction de station).

For the line OP, let $P_s$ be the parallax of the base point and $P_b$ that of the objective.

The station correction is $P_s - P_b$.

In the figure, if O is the angular distance measured at the observation post, the angular distance P at the base piece is:

$$P = O + P_s - P_b.$$

The sign of the station correction depends on the relative position of the points involved. It is **positive** if P is inside of a circle through O, B, and S, and **negative** if it is outside of this circle.

The most rapid method of determining the sign is to move from the observation post toward the battery, without losing sight of S and B, and note whether the angular distance from S to B increases or diminishes. If the former, the station correction is positive; if the latter, it is negative.

The range may be obtained from the objective to the observation post (BO), by range finder or estimation, corrected by the projection of the line battery—observation post (PO) on the line BO.

The site is calculated as in paragraph 182.

These rough methods are admissible only when the battery and observation post are little separated. When this is not the case, the **place sketch must be used.**

## STUDY OF FIRING CONDITIONS.

**184.** The **character of the objective** governs:

The kind of fire (time or percussion).

The projectile and fuse.

The conditions to be fulfilled by the angle of impact (angle between the trajectory and the surface of the ground at the point of fall) will depend on the decision made as to these two elements and what effect on the objective is desired.

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Let $C_1$ and $C_2$ be the permissible limits of the angle of impact. The angle of fall (par. 4) must be between:

$$a_1 = C_1 + S - n \text{ and}$$
$$a_2 = C_2 + S - n.$$

The site, S, and the slope of the ground (fig. 42) near the objective, $n$, should be taken with their sign (pars. 4 and 178). Seek in the firing tables, for the range D, the charges which give angles of fall between the limits thus obtained, $a_1$ and $a_2$.

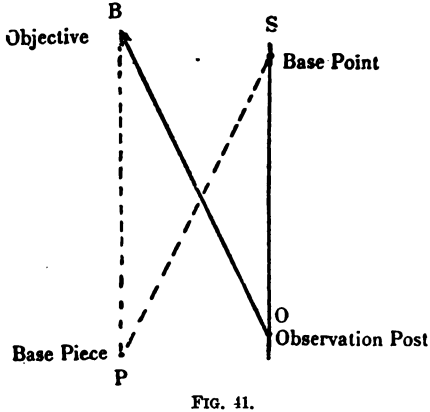


FIG. 41.

If none are found, or if those found leave too small a margin for adjustment, then the fire is impossible under the conditions imposed as to angle of impact. The fire is entirely impossible if these conditions are based on the form of the terrain.

If several suitable charges are found, as a rule the smallest should be used, in order to avoid unnecessary wear on the matériel. The heavier charge should be used only in the exceptional case where it gives materially greater accuracy of fire and where this accuracy is essential.

To compare the dispersions of different charges, find the probable error on the slope considered (par. 21).

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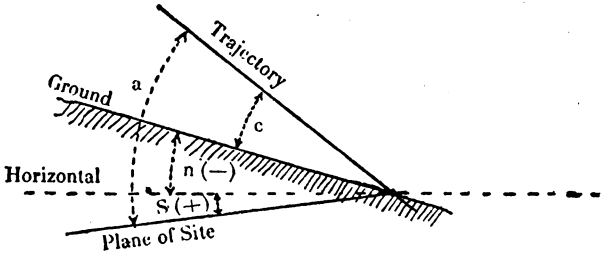
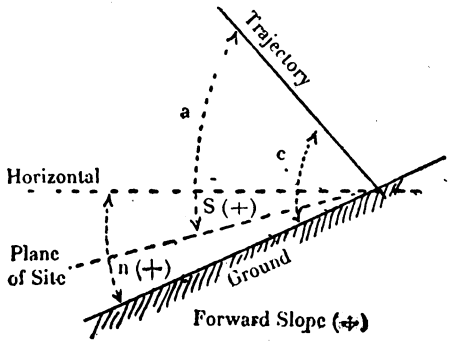
Having decided upon the charge to be used, make sure that there are no intervening features which prevent the objectives from being reached (par. 61).




Reverse Slope (−)




Forward Slope (+)

FIG. 42.

**185.** Determine the method of fire for effect, according to the time and means available, and the nature, front, and depth of the objective. Then decide on the methods of adjustment and observation.

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## DETERMINATION OF THE INITIAL FIRING DATA.

**186.** This includes:

Miscellaneous entries on the **data sheets** (feuilles de calculs).

Preliminary calculations which can be made as soon as the map data in regard to the objective has been obtained and firing conditions decided upon.

Final calculations, which can only be made at the time of firing, when the meteorological data are known.

**187.** (1) **Miscellaneous entries and preliminary calculations.**—First enter the following on the data sheets:

(*a*) Coordinates and altitude of the battery.

(*b*) Coordinates and altitude of the objective (adjusting point of the base piece), difference in level between the objective and the battery, map range, site, and deflection change.

(*c*) Data in regard to ammunition: Kind of projectile, weight of projectile (filled and fused), kind of fuse and powder, designation of powder lot.

**188.** (*d*) The adjustment coefficient $K_o$ (or the velocity correction), obtained from previous fire with the powder lot to be used.[1]

**Modified range,** map range A multiplied by the adjustment coefficient $K_o$, or map range modified for the velocity correction, $V-V_o$.

(*e*) Charge to be used. Maximum ordinate for the corrected range.

(*f*) Base deflection for each piece. Deflection corrections from previous adjustments.[2] Correction for drift.[3]

**189.** (*g*) Distribution corrections.

If the pieces are **regularly spaced** and the distribution to be obtained is **regular,** calculate the change in deflection difference, *c*;

---

[1] The coefficient $K_o$ for previous firing with a given powder lot is the ratio of the stripped range to the map range (Appendix 14).

The velocity correction, $V-V_o$, is that which, for the powder lot in question, corresponds to the difference between the stripped range and the map range (Appendix 14).

If previous firing with the same powder lot is not available, take $K_o$ as 1, or else as the mean of the values obtained for all lots of the charge used.

[2] If there has been no previous firing, take these corrections as 0.

[3] For high angle fire, this correction can not be entered until after the corrected initial range has been determined (par. 192).

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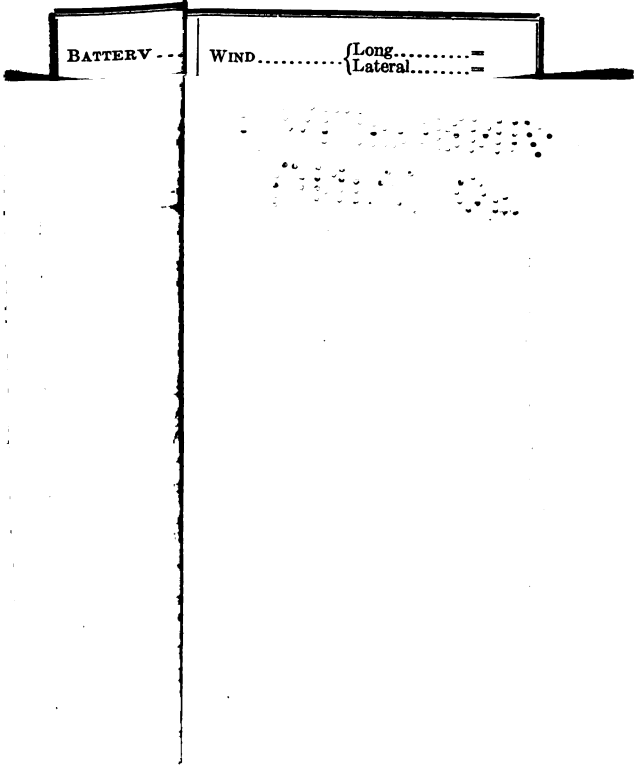


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Battery
Date:
Hour:

TYPE 2 ($dV_o$).

osition .....

BATTERY.....

WIND.....{Longitudinal..=
Lateral

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$e$ is equal to one-fourth of the parallax of the battery for the front of the objective, **less** one-third of the parallax of the objective for the front of the battery.

The distribution corrections for the various pieces are $+e$, $+2e$, $+3e$, depending on the direction of the sight graduations and the position of the pieces with respect to the base piece.

If the pieces are **irregularly spaced,** or if the various pieces are to be directed at particular points of the objective, calculate the distribution correction individually for each piece.

The distribution correction for a given piece is the parallax of the battery for the interval between the objective of this piece and that of the base piece **less** the parallax of the objective for the interval between the given piece and the base piece.

(*h*) For each piece, find the algebraic sum, Δ (uncorrected deflection), of the base deflection, deflection change, and distribution correction.

**190.** (2) **Final calculations at the time of firing.**—(*a*) Collect the meteorological data:

Velocity and direction of the wind for the appropriate maximum ordinate. Temperature and barometer for the battery position (weight of a liter of air in milligrams).

(*b*) Take the powder temperature.

**191.** (*c*) **Initial deflection.**—Calculate the correction for the lateral wind.

Take the algebraic sum of the wind and drift corrections.

Obtain the initial deflection by adding this sum to the uncorrected deflection.

The initial deflection for each piece is obtained in this manner.[1]

**192. Initial elevation or range.**—For the **modified range** (par. 188), calculate from the firing table the **corrections** for:

First. Variation of the weight of a liter of air.

Second. Longitudinal wind component.

Third. Variation of the weight of projectile.

Fourth. Variation of muzzle velocity due to the powder temperature.

[1] The chiefs of section take into consideration the individual sight corrections (Appendix 13).

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Take the algebraic sum of these corrections, which is the total correction M′.

The modified range corrected by M′ gives the **corrected range** $A_c$.

For high-angle fire, also add the site correction

$$\frac{H'-H}{2}\text{(par. 36)}$$

to obtain the corrected initial range.

**193. First case—Laying by quadrant—Initial quadrant elevation.**—For direct and curved fire, take from the firing tables, for the charge and projectile used, the elevation for the range $A_c$.

Increase the elevation algebraically by the total site correction,[1] thus obtaining the initial quadrant elevation for the base piece.

For high angle fire, take the tabular elevation for the corrected initial range and neglect the site.

**194. Second case—Laying by a range scale.**—Generally, the site and range settings are taken as follows:

*Site.*—That of the objective, modified by the complementary site correction.

*Range.*—The setting corresponding to the corrected range $A_c$ of the base piece.

**195. Third case.**—If the correct site is not set on the site scale, find the difference $d$,

$$d=\text{corrected site}-\text{site used.}$$

In the firing tables, find the variation in range which, for the range $A_c$, corresponds to $d$. Give it the same sign as $d$. Add this variation algebraically to the range $A_c$, and take out the corresponding range setting.

**196. Remark.**—Sometimes it is necessary to determine range elements for pieces other than the base piece, in order to take into consideration:

First. Differences in map ranges caused by the obliquity of the battery or the objective to the planes of fire.

Second. Differences in altitude among the pieces of the battery or within the objective. Let $dh$ be the difference in level of a piece

[1] The site modified by the complementary site correction.

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with respect to the base piece, $dh'$ the difference in level between the objective of this piece and that of the base piece, and $\omega$ the angle of fall. The range correction is then:

$$\frac{dh' - dh}{\tan \omega}$$

These individual corrections are converted into angles and given to the chiefs of section. The latter add the individual corrections (Appendix 13).

**197. Initial fuze setting**—(*a*) **Fuse punch or fuze setter graduated in time.**—For the charge and projectile used, take from the firing tables the fuze setting for the initial elevation, modified by the site with changed sign.[1]

Modify this setting for the altitude or barometer, by means of the data in the firing tables.

If the time fire is preceded by percussion fire for adjustment use the adjusted elevation for the fuse setting, instead of the initial elevation.

(*b*) **Fuze setter graduated in range.**—Use the same range setting for the fuze setter as for the piece.

If appropriate, modify the normal corrector (correcteur normal):

(*a*) As indicated by the firing tables.

(*b*) To offset the error in the site used, correct site—site used (algebraically).[2]

(*c*) For the altitude or barometer.[3]

**198.** The methods explained in the preceding chapters are for the deliberate preparation of fire.

Generally, it is better to devote a little more time to the preparation of fire and have the first salvos close to the objective, thus saving ammunition, and facilitating and hastening the adjustment.

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[1] The site only, and not the total site correction (par. 50), if the site is great.

[2] See par. 195. Complementary site correction not included.

[3] When this correction is large, the firing tables prescribe that a part should be made by changing the site. This change should not enter into the calculation of the site error.

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However, in certain cases and often for considerations of morale, the preparation of fire must be reduced to the minimum. The error resulting from the rapid determination of the elements of fire will then be corrected by the firing itself.

The time necssary for the preparation of fire and its accuracy depends largely on the skill and experience of the battery commander.[1]

[1] It is indispensable that all artillery officers, particularly those of light artillery, be frequently practiced in the rapid preparation of fire.

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# PART V.

## PRINCIPLES AND METHODS OF FIRE.


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## CHAPTER 1.

## GENERAL REMARKS AND DEFINITIONS.

**199. General remarks.**—The essential aim of artillery in war is to **destroy** the enemy.

Destruction being impossible, the artillery will attempt to **neutralize** the enemy by causing a cessation or at least an abatement of his activity.

In addition, the artillery affords **moral support** to friendly troops by **diverting** the attention and blows of the enemy.

Its accuracy and rapidity of fire enable a maximum of effect to be obtained with the minimum expenditure of time and ammunition.

**200.** Effects of neutralization, moral support, and diversion result from the known efficacy of artillery. They are none the less tangible in spite of the fact that they can be produced by a fire whose real efficacy is little or nothing. These effects should be borne in mind when it is a question of hastening or delaying the opening of fire, increasing or diminishing its intensity, or suspending or resuming the fire.

The result sought will be the more surely obtained when it is supported by a real effect, as great as possible.

**201.** Destruction of the enemy can be expected only as a result of precision fire.

Zone fire, however, delivered by surprise and in sufficient density upon an exposed animate objective (infantry, artillery, cavalry), may cause very serious losses, or even temporary annihilation.

**202.** In general, all fire consists of **fire for adjustment** (tir de réglage) and **fire for effect** (tir d'efficacité).

Fire for adjustment is to determine the data to be used in fire for effect.

**203.** Fire for adjustment consists as a rule of **trial fire** and **improvement fire** (tir d'essai, tir d'amélioration). This applies to



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precision or complete adjustment (réglage de précision). Trial fire places the zone of dispersion of a single elevation so as to include the objective. Improvement fire places the center of this zone at or near the objective.

In certain cases, fire for adjustment is carried only to the point of obtaining a bracket, which is called a **bracket adjustment** (réglage d'encadrement).[1]

**204.** Fire for effect is classified as **precision** or **zone**.

In precision fire for effect, the object is to keep the center for each piece in the immediate vicinity of its particular objective. **Laying for range is always by quadrant.**

In zone fire for effect, the object is to distribute the shots in a more or less regular manner over a zone which includes the objective. **Fire at a single range** is a special case of zone fire.

**205.** A **salvo** is a series of one shot per piece fired at regular intervals from one flank to the other of a unit of artillery.

A **volley** is a series of one or more rounds per piece fired as rapidly as the matériel permits. Each piece is served independently of the others.

Volleys or salvos at successive ranges may be used in zone fire.

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[1] Testing fire (par. 171) is two or three rounds per piece fired under certain conditions to verify the deflection and distribution.

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## CHAPTER 2.

## FIRE FOR ADJUSTMENT.

**206.** This will be taken up under the following headings:
Percussion precision adjustment.
Percussion bracket adjustment.
Time fire adjustment.

### PERCUSSION PRECISION ADJUSTMENT.

**207. Conduct of the adjustment.**—Each piece is adjusted in deflection and range on the particular adjusting point assigned to it.

If the observation is aerial and the front of the objective does not exceed 10 mils (normal case for counter-battery work), the adjusting point is taken for all pieces at the center of the objective.

Each piece is separately adjusted. Fire may be by piece or battery salvo.

The time interval for salvos is generally 5 seconds, but may be modified to suit the observer.

**208. Deflection adjustment.**—Bold deflection changes should be made at first to obtain rapidly a deflection bracket. The deflection changes are then measured.

When the deflection deviation of a shot is not more than four probable errors,[1] the deflection is not changed until several successive and concordant shots show it to be advisable. In this case make a change equal to the mean of the several deviations observed.

**209.** If the first deflection is seriously in error, make a change for the battery to bring the sheaf on the objective. Then proceed by individual corrections.

**210.** If the observer does not see the shots, time fire may be used to place the sheaf in direction, the bursts being raised to a suitable height by the quadrant or fuze.

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[1] Except for trench mortars and high-power guns, 3 mils or 2 decigrades may be taken as a sufficiently accurate value for four deflection probable errors.



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**211. Range adjustment.**—For terrestrial observation, the range adjustment is begun as soon as the deflection is sufficiently adjusted to permit observation for range. From this time on, the two adjustments are conducted simultaneously. If the observer displacement is great, it may be necessary to proceed in the inverse order, the range being first adjusted (par. 98 and seq.).

**212.** If the visibility is poor, it may be necessary to fire the first salvos rapidly or even to use volleys. With rapid fire matériel (75 or 105), the volleys may be of two or three rounds each. Later, salvos at the normal rate may be resumed.

**213. Verifying an elevation.**—During trial fire, the sense of an elevation is verified by obtaining at least two successive observations at this elevation (par. 236).

Two observations in the same sense establish the sense of the elevation used.

If two observations are opposite in sense, the elevation is **bracketing.** This requires two more observations at the same elevation. If these observations are in the same sense, the elevation is taken in this sense. If they are again opposite in sense, the elevation is tentatively taken as correct.

**214.** If a shot is observed at the objective (target shot), the elevation should be considered as bracketing and verified as just described.

**215. Trial fire.**—The object is to **bracket** the objective between two **verified** elevations differing by **one fork** (6 tabular probable errors or 4 field probable errors), one of the elevations being short and the other over; or to find a **verified bracketing range.**

The mean of the bracketing elevations or the bracketing elevation is called the **trial elevation** (angle d'essai). The zone of dispersion of the trial elevation includes the objective with a high degree of certainty.

To obtain the bracket, begin with the elevation calculated in the preparation of fire, and proceed by bounds of one fork.[1]

Verify the limits of the bracket or the bracketing elevation.

---

[1] If the objective is very close to the friendly lines, begin with an elevation which is surely over, and proceed by changes of a fraction of a fork.

For certain mortars, the first shot, called the drying shot (coup de flambage), should be disregarded except for deflection.

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**216.** If the preparation of fire has been rapid, and if the first shots are clearly distant from the objective, the first elevation bounds should be two or four forks, so as to bracket the objective rapidly.

The bracket is then reduced to one fork and the limits verified as explained in paragraph 213.

**217.** If as many as two shots at the same elevation are not observed, and this is apparently due to the terrain, bold elevation changes should be made to secure observations rapidly. After a bracket is obtained it should be reduced to one fork, if not already of this size.

**218.** When it is possible to measure the range deviation of shots (observation by aeroplanes or topographically) the first elevation is corrected to measure. Then proceed by bounds of one fork (par. 228).

**219. Improvement fire.**—The object is to find an elevation giving substantially as many observations short as over.

With the trial elevation, fire 12 shots per piece. If there is not for each piece an equality of shorts and overs, modify the elevation by as many **twelfths** of a fork as there are shots to be changed in sense to obtain this equality.

The elevation thus obtained is called the **adjusted elevation** (angle de réglage).

**220.** If only a limited time is available for adjustment (as in observation by aeroplane), the number of observations in improvement fire may be less than 12, but not less than 6, per piece.[1]

The changes in the trial elevation are then made by sixths, eighths, etc., of a fork.

**221.** With trench artillery, on account of its slow rate of fire, 6 shots per piece are habitually used in improvement fire.

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[1] With aeroplane observation, when the objectives of the various pieces are well separated, and when rapid-fire materiel is used, it is often best to deliver the improvement fire by piece. This is specially applicable when the individual pieces require a very accurate adjustment in direction.

**Each piece fires two series of 4 shots each at the signal of the observer.** After each series the observer reports the deviation of the detection center and the number of shorts, overs, and targets for range.

If the battery commander makes considerable corrections, as a result of the first series, he calls for the observation of a second series like the first.

This modification is made necessary by the fact that a series of more than 4 consecutive shots can not be properly observed.

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**222.** If in an improvement fire of 12 shots per piece the first 6 are in the same sense, the elevation is changed by a half fork and 6 more shots fired. The series of 12 shots is taken as having been fired with the mean of the two elevations used, and the correction is referred to this mean elevation.

If the last 6 shots are in the same sense as the first 6, the adjustment is begun anew.

**223.** In curved fire the charge is chosen to give an angle of impact greater than a certain determined minimum. After the trial elevation has been determined it must be examined to insure that it has a suitable angle of impact.

If the charge used is found to give too small an angle of impact, it is necessary to pass at once to the next lower charge and begin the adjustment anew. The initial elevation with the new charge should be that corresponding to the adjusted elevation with the old charge. The deflection must also be changed to take into account changes which result from the altered charge and elevation.

**224.** If the adjustment yields an observation short with an elevation of 36° for curved fire, or of 50° for high-angle fire, pass to the next higher charge and begin the adjustment anew.

**225. Change in the firing conditions.**—If, during the fire, the powder lot is changed,[1] begin the adjustment anew.

**226.** If, during firing, the projectile is changed without changing the powder lot, the elevation and deflection should be corrected from the firing tables and **verified** by firing.

This verification consists of firing two rounds with the new data. If they are of the same sense, the trial fire should be begun anew, using changes of a half fork. After a verified bracket is obtained pass to improvement fire.

A single piece may be used, for it gives a correction to be applied to the tabular elements which is applicable to all the pieces.

**227.** If the kind of fuse is changed during firing, proceed as explained in the preceding paragraph.

**228. Adjustment by means of the measured deviations of the shots.**—If the means of observation permit the deviation of the shots to be accurately measured by plotting them on a photo-

[1] If the new powder lot has not been used in recent previous adjustments.

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graph or squared map (observation by aeroplane or topography), the following method may be used:

Correct each round by the observed deviation **divided** by the serial number of the round.

The first two shots are numbered one.[1] Those not observed are not numbered.

The fire is considered adjusted when three times in succession the range correction [2] is less than one-sixth of a fork and the deflection correction less than one probable error.

This method of adjustment should be used only when the rate of fire is sufficiently rapid to insure the series being fired under the same atmospheric conditions.

Moreover, the rule "divide the deviation by the shot number" is only applicable up to a limited number, 6 for example. If after 7 shots (the first included) the adjustment has not been secured, a new series of numbers should be begun, applying the rule as before.

### PERCUSSION BRACKET ADJUSTMENT.

**229.** This method is used when the time or means for a precision adjustment are not available, or when the objective is moving or transient.

It is immediately followed by zone fire for effect (par. 257 et seq.). The depth of the beaten zone depends on the objective and on the time and means of observation available.

The method is as follows:

**230. Deflection adjustment.**—In general the fire is distributed over the front of the objective, assigning to each piece an appropriate portion.

If the front of the individual piece is not larger than can be effectively covered, using a single deflection, each piece is laid on the center of its portion.

In the contrary case, each piece is laid on the right element of its portion.

[1] The adjustment, properly speaking, begins only with the second shot. The first shot simply gives measurements by which those following can be placed close to the objective, where the deviations can be accurately measured.

[2] It is a question of the correction, and not of the deviation on which it is based.

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The deflection changes necessary effectively to cover the individual portions are made during fire for effect.

**231.** With terrestrial observation the adjustment should, from the first, be on the visible portions of the objective.

But in all cases care must be used to avoid crossing or confusing the sheaf, so that, in passing to fire for effect, only a simple change in deflection difference will be necessary.

**232.** With aerial observation, the right of the sheaf should be directed on the right of the objective. The sheaf is then opened or closed to secure proper distribution.

**233. Range adjustment.**—The adjustment is made for the battery as a whole, it being assumed that the pieces are calibrated. The chief of section changes the data received by the individual corrections for his piece (Appendix 13).

The firing is by salvos.

**234. Method of adjustment.**—Begin with the initial range setting or elevation corresponding to the range determined,[1] taken in even hundreds of meters or tens of minutes.

Proceed by successive bounds in elevation until a bracket is obtained.

The size of the bracket is generally two forks.[2]

When the objective has little depth and is clearly visible the bracket may be decreased to one fork.

**235.** When the objectives in a locality are numerous and it is feared that the observations made during adjustment for zone fire may be erroneous due to confusion with fire for effect on nearby objectives, the bracket is narrowed to a half fork.

**236.** A single observation is a sufficient basis for changing the elevation. But an elevation should be taken as the limit of a bracket only when based on two or more like observations in the same or different salvos.

**237.** If a bracketing battery salvo is observed (two shorts and two overs), the adjustment should be considered as terminated. If one short and one over are observed in a salvo, the range is bracketing, but should be verified by another salvo at the same elevation. If

[1] Increase this range for safety if the objective is close to friendly troops.

[2] When the objective is close to friendly troops the elevation change must be decreased to avoid endangering these troops.

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two or more observations in the same sense are obtained with this salvo, the elevation is taken in this sense. If the salvo yields both shorts and overs, the elevation is accepted as that corresponding to the objective.

**238.** A target shot should be treated in the same manner as two observations one short and one over.

### TIME FIRE ADJUSTMENT.

Time fire may be:

(*a*) With shrapnel.

(*b*) With H. E. shell.

**239. Time shrapnel adjustment.**—Shrapnel time fire is always a zone fire and the adjustment is a bracket adjustment (par. 229 et seq.).

The fuse setting is said to be adjusted when a battery salvo gives two bursts above and two below the normal height of burst.

**240.** The following are taken as the normal heights of burst. They are referred to the plane of site through the base of the objective.[1]

| Muzzle velocity. | Normal height of burst. |
|---|---|
| | *Mils.* |
| Over 500 meters | 2 |
| 500 to 400 meters | 3 |
| 400 to 300 meters | 4–8 |
| 300 to 200 meters | 8–12 |

**241. Method of adjustment.**—If the observation is terrestrial and percussion bursts are visible, first adjust the range and direction by percussion fire, as described under bracket adjustment (par. 229; see also par. 245).

[1] When the objective is defiladed, the height of burst adjustment must be made with respect to the covering crest, and the normal height modified to take into account the defilade of the objective.

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**242.** Then take from the firing tables the initial fuse setting, in seconds and tenths, corresponding to the short limit of the adjusted bracket.

For fuse setters, graduated in range (or time), use the normal corrector [1] and the range setting of the short limit of the bracket (or the fuse setting for a 0 height of burst, diminished by as many **tenths** of seconds as there are **mils** in the normal height of burst).[2]

**243.** Using the initial fuze setting thus determined, begin with battery salvos in time fire, with 1 or 2 seconds between shots.

**244.** If the first salvo gives only air bursts, estimate the height of burst center, and correct the fuze setting for the deviation with respect to the normal height of burst.

If the first salvo is all on graze, decrease the fuze setting 4 tenths or raise the corrector 4 points. Double this change if the next salvo is still on graze, in order to obtain air bursts as rapidly as possible.

When a salvo yields two air bursts and two on graze, the most probable position of the height of burst center is 0. It is 1 mil above the ground when 3 air and 1 graze bursts are obtained, and 1 mil below the ground when 3 graze and 1 air bursts are obtained. Corrections to obtain the normal height of burst can be made accordingly.

During fire for effect, the adjusted fuze setting previously obtained should be modified only when this is shown to be necessary by a greater number of rounds than that on which the adjusted setting was based.

**245.** With aerial observation, or when the battery and the terrestrial observation post are at widely differing distances and altitudes with respect to the objective, or when percussian bursts are not easily observable, or when a rapid adjustment is necessary, use time fire from the beginning.

Use an initial fuze setting determined to give a 1 mil height of burst.[3]

Fire battery salvos at 1 or 2 seconds interval.

Raise or lower the bursts so as to obtain a height of 1 mil which can be judged by the proportion of air to graze bursts (par. 244).

---

[1] When necessary, take into account differences for the charge and projectile used between the gun ranges and the fuze setter ranges.
The normal corrector is that which gives a normal height of burst.

[2] Matériel not provided with fuze setters.
With aerial observation, use a fuze setting which will surely give air bursts.

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Adjust the deflection and the range so as to obtain the desired bracket.

Then raise the bursts to the normal height.

If, during the adjustment, a salvo in air gives **bursts** short and **bursts** over, the elevation may be taken as over but near the objective. The next change in elevation may be a half fork.

**246.** The method of the preceding paragraph is applicable to time fire against a wood.

Use bursts at the top of the trees. In passing to fire for effect, modify the height of burst by a suitable amount.

**247. Time shell adjustment.**—Time shells are especially effective when the bursts are about 20 meters above the ground.

They are effective against personnel in trenches, but in this case a precision adjustment is necessary.

**248. Method of adjustment.**—The adjustment of time shell differs materially from that of percussion shell and time shrapnel. It consists of placing the burst above the target, and the raising it to the most effective height.

**249.** The operations are as follows:

(*a*) Deflection adjustment.

(*b*) Burst range adjustment, by means of the fuze setting and elevation.

(*c*) Height of burst adjustment by raising the trajectory.

**250.** The deflection and range of burst are adjusted when the burst center is directly over the adjusting point.

This is accomplished by the observation of low air bursts, by the observation of the effect on the ground of high air bursts, by aerial observation, or by bilateral observation.

**251.** The height of burst is adjusted with respect to the adjusting point, by changing the elevation without changing the fuze setting.[1]

With matériel where the site is set separately, the height of burst may be adjusted by site changes. The proper height in mils is given by $\frac{20}{P}$, where P is the range in kilometers.

---

[1] It is sometimes impossible to use low air bursts in adjusting the height of burst, because of the difficulty of distinguishing ricochets from air bursts. In this case, the adjustment should begin with high air bursts, with subsequent modification of the height of burst by changing the elevation.

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For other matériels, the quadrant elevation must be changed, the amount in minutes for a height of 20 meters being obtained from the firing tables.

**252. Practical methods.**—From the firing tables for the charge and projectile used, take the fuse setting for the map range. Correct it for the atmospheric conditions and the altitude, by means of data in the firing tables.

Start with an elevation which is surely too great, in order to obtain air bursts. The height of burst can then be raised to a suitable height, depending on the method of adjustment used, by changing the elevation.

Bracket by changes in fuse setting corresponding in range to the values of the fork given in the firing tables.

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## CHAPTER 3.

## FIRE FOR EFFECT.

**253. General remarks.**—Fire for effect may be classed as—

Percussion precision fire for effect.

Percussion zone fire for effect.

Time fire for effect.

Percussion precision fire for effect is always preceded by a precision adjustment.

The adjusted elevation being only approximate, fire for effect must therefore be observed for a sufficient number of rounds surely to determine the **elevation for the objective** (angle du but); which gives an equal number of observations short and over.

Moreover, the elevation for the objective is constantly subject to change on account of the heating of the pieces, so that practically constant observation during fire for effect is necessary.

Percussion zone and time fire for effect are based either on—

A precision adjustment on a datum point and a shift of fire (pars. 281 and seq.), when the objective is not clearly defined or is of great extent, or a bracket adjustment (pars. 229 and seq.), when the time is short, as in firing on a moving objective.

### PERCUSSION PRECISION FIRE FOR EFFECT.

**254.** The ammunition is H. E. shell.

Observation must as far as practicable be continuous throughout precision fire for effect.

Battery salvos from the right or left,[1] with 1 or 2 seconds interval, should be used.

The firing is by series of 24 or 48 rounds. During the fire, the observer notes the sense of each round, and at the end of the series reports the result as a whole.

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[1] With terrestrial observation, if the wind comes from the left, fire should be from the right.



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Based on this report, corrections are made if necessary to obtain an equal number of shorts and overs.

Individual corrections are made only when the number of shots observed is at least equal to the number observed during improvement fire.

**255.** With aerial observation when, as a result of the first series of 24 shots, the battery commander is satisfied with the adjustment, he may pass to continuous fire, to save time. Aerial observation is continued.

If the firing becomes faulty, adjustment by salvos is resumed at the request of the observer.

In this kind of fire, it is very important that accuracy, and with it effect, be not sacrificed for speed.

**256.** When firing becomes faulty, the observer makes a point of ascertaining whether a particular piece is responsible, or whether it is due to the battery as a whole.

In the former case, he reports the piece which is out, and if possible the sense and amount. The elevation of this piece is then corrected, and fire by series resumed.

If the piece can not be corrected, it ceases firing, and fire for effect is continued with the rest of the battery.

If the fault is due to the battery as a whole, the adjustment must be begun again.

### PERCUSSION ZONE FIRE FOR EFFECT—METHOD OF FIRE.

**257.** The ammunition is H. E. shell. The object is to deliver as rapidly as possible a fire whose mean density (number of shots per hectare [1] of objective) is not less than:

80 for the 75 or 90.
45 for the 105 or 120.
30 for the 145 or 155.

The fuzes, depending on the range, the ground, and the nature of the objective, should be instantaneous, nondelay, or short delay.

**258.** The front to be covered is divided into as many portions as there are pieces available.

[1] A hectare is 10,000 square meters, equal to a square 100 meters on a side.

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The planes of fire are directed initially as explained in paragraph 230.

Each piece fires one [1] shot at each range for the first deflection. The deflection is then changed by the proper amount (par. 260), and the fire repeated.

This sweeping is continued until the portion assigned to each piece has been completely covered.

The fire is begun at the elevation corresponding to the short limit of the bracket. The elevation is changed progressively by amounts corresponding to 25 meters for the 75, or 50 meters for the 105 or 155.

**259.** The fire is by the command: "Zone fire," followed by commands giving the limiting elevations, the elevation bound, and the deflection bound.

**260.** The values of the deflection bound in mils are given in the following table:

| Range. | Mils.* | | | Remarks. |
|---|---|---|---|---|
| | 75 | 105 | 155 | |
| 2,000..... | 5 | 6 | 10 | * These values may be converted into turns of the traversing handwheel. |
| 3,000..... | 3 | 4 | 7 | |
| 4,000..... | 2 | 3 | 5 | |
| 5,000..... | 2 | 2 | 4 | |
| 6,000..... | 1 | 2 | 3 | |
| 7,000..... | 1 | 2 | 3 | |
| 8,000..... | ..... | 1½ | 2½ | |
| 9,000..... | ..... | 1½ | 2 | |
| 10,000..... | ..... | 1 | 2 | |

[1] This number should be increased if the objective is on a reverse slope (par. 21).

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When the deflections are in decigrades, the following table is applicable:

| Range. | Decigrades. | | |
|---|---|---|---|
| | 0 | 120 | 155 |
| 2,000 | 3 | 3 | 6 |
| 3,000 | 2 | 3 | 4 |
| 4,000 | 1 | 2 | 3 |
| 5,000 | 1 | 2 | 2 |
| 6,000 | 1 | 1 | 2 |
| 7,000 | ..... | 1 | 2 |
| 8,000 | ..... | 1 | 1 |
| 9,000 | ..... | ..... | 1 |
| 10,000 | ..... | ..... | 1 |

**261. Systematic fire** (tir systématique).—Systematic fire is zone fire without preliminary adjustment.

The elevation for the objective is taken as the map range, corrected for the conditions of the moment as far as these are known.

The deflection for the objective is similarly obtained.

**Systematic fire for effect.**—The depth and width of the zone to be covered varies with the accuracy of determination of the firing data.

The depth should be not less than two forks.

### TIME FIRE FOR EFFECT.

**262.** (1) **Shrapnel.**—Time shrapnel fire, when over by as little as a half fork, has little or no effect.

Against unsheltered personnel, such fire, when short by a half fork, is still effective.

When the height of burst is above the normal, much of the effect is lost.

Against sheltered personnel, time shrapnel fire has only a neutralizing effect.

Time shrapnel fire is always a zone fire.



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**263. Method.**—The distribution is made as explained in paragraph 230.

Each piece fires two rounds at each range and each deflection. The deflection bound used in covering the front is given by the following table:

| Range. | Mils. |
|---|---|
| 2,000 | 7 |
| 4,000 | 5 |
| 6,000 | 3 |
| 8,000 | 2 |
| 10,000 | 1 |

The elevation bound is taken uniformly at that corresponding to 100 meters.[1]

The fire is begun at the short limit of the bracket.

With the fuze setter, the fire may be executed at the command "Zone fire," followed by commands for the corrector, the limiting elevations, the elevation and fuze-setting bounds, and the deflection bound.

**264.** (2) **H. E. shell.**—The method explained for time shrapnel fire is applicable to time shell fire for effect, but, because of the greater dispersion, the elevation bound is that corresponding to 50 meters for all calibers. Three rounds should be fired at each elevation and deflection for the 75.

**265. Time fire behind crests.**—To cover ground behind a crest, it is desirable to displace the bursts parallel to the slope.

Determine the increments of elevation and decrements of corrector (or increments of fuze setting), so that the bursts will be displaced in a regular manner and parallel to the ground. Use for this purpose the slope charts for air bursts (abaque despentes des éclatements fusants), from which the following can be read directly: The elevation bound, the corrector or fuze-setting bound, and the actual bound on the ground (Appendix 15).

[1] The change should be increased when the objective is on forward slope.

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**266.** With shrapnel, seek a 100-meter bracket on the crest, using percussion fire.

Then adjust the height of burst at zero with respect to the crest, using the long limit of the bracket.[1]

With time shell, bracket the crest in time fire. Then raise the trajectory to obtain the proper height of burst, without changing the fuze setting.

**267.** Search the reverse slope, beginning with the data thus obtained, modified successively according to the chart.

Fire at each elevation and deflection, as described in paragraphs 262 to 264, but with—

For shrapnel, 2 or 3 rounds, depending on whether the range bound on the ground is less or greater than 100 meters.

For shell 3, 4, or 6 rounds, depending on whether the range bound on the ground is 50, 75, or 100 meters.[2]

**268. Remark.**—If, for considerations of safety, it is not possible to adjust on the crest, select a suitable point in the zone to be searched and adjust on it. Then, by using the chart, determine suitable data for the short limit of the zone. Verify this data by approaching the short limit with due caution by successive bounds. The fire for effect is then executed as previously described.

**269.** With the 75, and when there is no battle map giving the value of the slope, proceed as follows:

For shrapnel, use elevation increments of 50 meters and corrector decrements of 2, if the slope is small (60 mils). If the slope is considerable (90 mils), use elevation increments of 25 meters and corrector decrements of 3.

For shell, use elevation increments of 50 meters and corrector decrements of 1:

**270. General remark on fire for effect.**—The methods of zone fire for effect set forth in the preceding paragraphs contemplate searching an area with maximum rapidity. But they must not be

---

[1] For the 75, increase the elevation beyond the long limit by 75 or 50 meters, depending on whether the range is less or greater than 4,000 meters. For shrapnel, raise the corrector 2 mils.

[2] Time fire on a forward slope is executed in a similar manner, using appropriate charts.

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considered as applicable in all cases. In some cases (for example, interdiction fire and harassing fire), equal or greater efficacy will be obtained by a slow fire (salvos, volleys, or single shots), distributed irregularly so as to baffle the enemy.

Moreover, in general, surprise is an important element of effect on personnel. It is therefore advantageous to have a greater or less interval between fire for adjustment and fire for effect. Fire for effect may well be delivered in several installments, separated by irregular intervals.

**271. Fire on a moving or transient objective.**—Use zone fire (par. 257).

The adjustment must be made with all possible rapidity.

The adjustment may often be much abbreviated by a knowledge of the terrain and by previous firing.

In position warfare, a battery can nearly always begin fire for effect at once on an objective reported in movement within its normal zone of action

The adjustment is as for zone fire. But the bracket should be accepted only when the limit last determined is ahead of the objective. When the direction of movement of the objective is not known, the limit last determined should be the short one.

If the objective is obliged to follow a certain route, it is well for all or part of the battery to lay down a barrage on points which must be passed.

Against **tanks** advancing to the attack, the barrage is a suitable method. The fire is as rapid as possible. As soon as shots are observed short but not far from the objective, fire is continued at this elevation. When two overs have been observed, an elevation change is made to obtain shorts again, after which the process is repeated.

Moving objectives reported by aeroplanes are generally attacked with systematic fire. The aeroplane observes the fire, and at his signal, if necessary, the fire is begun anew after suitable correction of the initial data.

In this way it is possible to avoid the delays inherent to adjustment by aerial observation. Due to these delays, the success of zone fire which is preceded by an adjustment would be doubtful.

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## CHAPTER 4.

## SPECIAL SHELL FIRE.

### GAS SHELLS.[1]

**272.** Fire with gas shells may be—
(*a*) On a small objective.
(*b*) On an area.
Depending on its purpose, such fire may be—
Destruction fire.
Neutralizing fire.

**273. Destruction fire.**—This is with **lethal gases** in high concentrations, and is intended to produce casualties. The effect will be dependent largely on surprise, and on poorly adjusted or defective masks. It is accordingly desirable to concentrate a large number of batteries on the same objective.

It is ordinarily not profitable for more than two minutes at one time.

**274. Neutralizing fire.**—The fire is intended to lower the physical resistance and morale of the enemy and interfere with his activities by causing him to wear his mask continuously for a considerable time.

The result can be obtained most economically with **persistent** gases.

**275.** Destruction and neutralizing gas shell fire may be combined in various ways. The use of shrapnel or H. E. shell during gas shell fire adds to the enemy's confusion, and may induce him to remove his mask. But they should not ordinarily be used during destruction fire, because of the necessity of devoting all available guns to securing surprise effect and a high gas concentration.

Varied and well considered adaptations of these methods will increase the effectiveness of gas shell fire.

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[1] Taken from French, British, and American sources.



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### FIRE FOR ADJUSTMENT.

**276.** The methods of adjustment for H. E. shell are applicable in the case of gas shell. The trajectory of gas shell may be taken as the same as that of the corresponding H. E. shell.

Fire for adjustment is generally with H. E. shell, the gas shell being used only in fire for effect.

(*a*) On a **small objective,** a narrow bracket is sought and the trial elevation found (par. 215), but improvement fire is not executed.

(*b*) On an **area,** the adjustment is for percussion zone fire for effect, as described in paragraph 253.

### FIRE FOR EFFECT.

**277.** (*a*) **On a small objective,** such as a battery emplaced over a front of less than 100 meters, a group of trenches, or a road crossing.

**Method for destruction fire.**—Use fire at a single range (par. 201), the elevation being that corresponding to the mid-range of the bracket, if there is no wind; or the mid-range modified by one-sixth of a fork in the direction from which the wind comes, if there is a wind. The deflection should be similarly modified to the windward.

Fire as **rapidly as possible** the following number of rounds:

| | |
|---|---|
| The 75 | 200–400 |
| The 120 | 80–160 |
| The 155 | 50–100 |
| The 58 T. M | 20– 50 |

According to the range and front of the objective.

These figures are the maximum for extreme range and an objective of about 100 meters front, with a wind of 3 meters. The effect will extend about 100 meters to the leeward of the point of fall.

C. G. or P. G. gas should be used, or a mixture of 4 C. G. to 1 N. C.

**Method for neutralizing fire.**—The method of fire is generally the same as for destruction. Use persistent gas preferably. B. A. is particularly adapted to this purpose, but N. C. may also be used.

The effect will last several hours, but the best results are obtained by a slow fire for at least four hours, with occasional short bursts of rapid fire, particularly at the beginning and end.

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The following is a proper ammunition expenditure, based on four hours firing on a front of 100 meters and a wind of 3 meters:

| | *Rounds.* |
|---|---|
| The 75 | 500 |
| The 120 | 250 |
| The 155 | 200 |

**278.** (*b*) **On an area.**—This is preferably **neutralizing fire** (par. 277) with persistent gases.

The number of shells required depends on the gas used and the extent to be covered, as well as on the time the fire is maintained.

Using B. A. gas, for areas up to 10 hectares, the following is a proper ammunition expenditure **per hectare:**

| | Ammunition expenditure. | |
|---|---|---|
| | First half hour. | Each half hour thereafter. |
| | *Rounds.* | *Rounds.* |
| The 75 | 500 | 250 |
| The 120 | 140 | 70 |
| The 155 | 80 | 40 |

For areas between 10 and 50 hectares, this consumption should be halved. For areas greater than 50 hectares, one-fourth should be used.

With N. C. gas, the consumption should be from one and one-half to two times that for B. A. gas.

For **destruction fire** on an area with lethal gas shells, fire is delivered with range bounds of 50 meters for the 75 and 100 meters for the 155. The ammunition for each range is that stated for destruction fire on a small objective (par. 277-*a*)].

**279.** In combining destruction with neutralizing fire, lethal shells should not follow persistent gases until sufficient time has elapsed to permit the enemy to remove his masks. This is usually about three hours if B. A. or N. C. have been used.

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## SMOKE SHELLS.

**280.** The method of fire for adjustment is the same as for gas shell (par. 276) on a small objective or an area, depending on the conditions.

Fire for effect is generally at a single range (par. 204).

Weather conditions, particularly the wind, materially affect the rate of fire which must be used to establish and maintain a smoke screen.

On sunny days, when there are upward air currents, the ammunition consumption is greater than on cloudy days, when such currents do not prevail.

For a wind perpendicular to the front to be screened, the following may be taken as a general guide as to the ammunition required to screen 100 meters of front when there is no sun:

| | Wind velocity. | | |
|---|---|---|---|
| | 2 | 6 | 10 |
| | *Meters.* | *Meters.* | *Meters.* |
| The 75 | 200 | 400 | 800 |
| The 120 | 100 | 200 | 400 |
| The 155 | 80 | 170 | 350 |

For a wind across the front to be screened, the fire is concentrated to the windward of the objective. The distances the cloud will drift and still remain effective vary greatly, but may be taken roughly as follows: 75—800 meters; 120—1,200 meters, 155—1,500 meters.

In general, the center should be adjusted to the windward of the objective at such a distance as to permit the smoke cloud to form with maximum effectiveness. The rate of fire must be such as to maintain an effective screen.

Begin with a rapid fire for about five minutes to establish the cloud. The rate of fire can then be reduced and quickened, from time to time, to build up the cloud.

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## CHAPTER 5.

## STRIPPING AN ADJUSTMENT—SHIFTING FIRE.

### STRIPPING.

**281. To strip an adjustment,** and fire again with the same ammunition.

When the adjustment on an objective has been completed, the adjusted data may be used in determining the initial data for subsequent firing.

The first firing gives the adjusted data for the **conditions of the moment.**

The adjusted data are then stripped of the conditions of the moment, that is, corrected to normal conditions.

To fire again on the same objective, the stripped data, instead of the map data, are used as a basis for computing the initial data.

The adjustment is stripped immediately after the firing and the results entered in the data book.

By a comparison of the stripped data with the map data, adjustment corrections can be obtained. These can be utilized, to a certain extent, in the determination of the initial elements for firing on other objectives.

**282.** The utilization of a previous adjustment for the preparation of fire on other objectives presupposes—

(*a*) That the meteorological conditions, at the completion of the first adjustment, are known.

(*b*) That the subsequent firing is with the same powder lot as the first firing.

**283. Stripping for deflection.**—Add algebraically to the adjusted deflection the lateral wind and drift corrections, **changed in sign.** The result is the **stripped deflection.**

The difference, **stripped deflection** minus uncorrected deflection, $\Delta$ (par. 189-*h*) is $\delta$, the **deflection correction** (par. 188-*f*).

**284. Stripping for range.**



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(*a*) **Quadrant laying.**—To the adjusted elevation (par. 219) add the total site correction (par. 193), changed in sign ($-S$).

In the firing tables, find the range corresponding to this elevation.

To it add the algebraic sum, changed in sign, of the corrections for longitudinal wind, weight of a liter of air, weight of projectile, and muzzle velocity due to the powder.

The result is the **stripped range,** $A'$.

The adjustment correction is $A'-A$, where A is the map range.

Calculate the adjustment coefficient, $K_o$, or the velocity correction, $V-V_0$ (par. 188).

(*b*) **Laying by range scale.**

**Using the correct site.**—Convert the adjusted range setting into range, by means of the firing tables. Then find as in (*a*) the stripped range, the adjustment correction, and $K_o$ (or $V-V_o$).

(*c*) **Using an incorrect site.**—Calculate the stripped range, $A'$, as in (*b*).

A is then the range stripped of meteorological conditions but not of the site error. It can be used for subsequent firing on the same objective if the same site is used.

But before $K_o$ (or $V-V_o$) can be computed for use in connection with other objectives, $A'$ must be corrected for the difference, site used—correct site. Find the range variation corresponding to this difference, give it the same sign as the difference, and add it algebraically to $A'$. This gives the **completely** stripped range, $A''$.

Now calculate the adjustment coefficient, $K_o$, which is $\frac{A''}{A}$ (or $V-V_o$).

In each case, enter $K_o$ or $V-V_o$ in the data book.

**285. Calculation of the initial elements for new firing on the same objective.**

**Deflection.**—To the stripped deflection add algebraically the correction for lateral wind and for drift.

**Range.**—The same powder lot should be used.

Calculate the initial elevation or range setting, as explained in paragraphs 188 and 192, et seq., with the following modifications:

(*a*) Begin with the mean of the stripped ranges, instead of with the map range.

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(*b*) When using a range scale and an incorrect site, use the same site as previously and do not make a correction for the site error (par. 195).

### USING THE RESULTS OF PREVIOUS FIRING.

**286. Deflection.**—(*a*) If the deflection corrections obtained from firing on several well-defined objectives differ but little, it points to an error in the initial establishment of the battery.

The base deflections of the various pieces are, therefore, corrected by the mean of the errors thus indicated.[1]

Thereafter, the deflection corrections should be small. They are more for use with the objective for which they are determined and not with new objectives.[2]

(*b*) **Range.**—When several series of firing with the same powder lot give adjustment coefficients $K_0$ (or velocity corrections, $V-V_0$), differing but little, the mean of the several values is used in determining the modified range (par. 188) for new objectives, provided the same powder lot is used.

(*c*) **Position of objectives on the map.**—When, for a particular objective, the deflection correction is considerable or the adjustment coefficient (or $V-V_0$) differs materially from the mean value for the powder lot, the calculations should be verified.

If the calculations are found to be correct, the position of the objective on the map is incorrect.

This error is corrected and communicated to the other batteries if necessary.

### SHIFTING FIRE.

**287. Shifting fire.**—When observation on an objective is poor or impossible, the methods of adjustment heretofore described are not applicable.

---

[1] The source of the error should be sought by going over the preliminary topographical operations. If the error is found in the determination of the orienting line, it should be corrected. The base deflections of all batteries using this orienting line should of course also be corrected.

[2] In view of the accuracy of the topographical operations of the establishment on the base line, if carefully made, the base deflections should be changed after several series of firing have shown the necessity of it; or in case the first adjustment shows a gross error in deflection.

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In this case, the method of shifting fire is used, in conjunction with a **datum point** (but auxiliaire), selected within the objective itself or near it.

**288. Definitions.**—A **datum point** is a clearly visible point selected as an adjusting point. It must be shown on the battle map, or be capable of being accurately plotted, and must satisfy the conditions of paragraph 292.

**Shifting fire** (transport de tir).—This is the operation incident to firing on an objective, based on the data obtained from firing on a datum point.

**289.** It is essential that the datum point, the objective, and the battery position be accurately plotted on the battle map (par. 95).

The firing on the datum point and on the objective is with the same kind and weight of projectile, same fuze, and same powder lot.

**290. The method.**—(*a*) Prepare the fire on the datum point, and fill out the data sheet, using $K_o$ (or $V - V_o$) for the powder lot and the deflection correction as found from previous firing. Prepare in the same manner a second data sheet for the objective except those parts involving $K_o$ or $\delta$.

(*b*) Fire for adjustment on the datum point to include improvement fire (par. 219).

(*c*) Strip this firing on the datum point data sheet, and find—

(1) $K_o$ (or $V - V_o$).

(2) The deflection correction for each piece.

Enter these values on the objective data sheet and complete the calculations for the objective.

This gives the most probable elevations and deflections for the invisible objective.

(*d*) Execute systematic fire, beginning with this data, and opening out 8 mils (5 decigrades) on each side and a half fork both short and over.

**291. Remark.**—The center of 12 observed shots on graze may be taken as a datum point, when this center can be accurately located on the battle map (bilateral observation or by the flash-ranging groups).

**292. Conditions for shifting fire.**—The shift is the more accurate, as it is small in both deflection and range.

The deflection shift should in general not exceed 300 mils (200 decigrades) and the ratio of the ranges should be between 3–4 and 4–3.

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A shift of fire should not be undertaken when the powder lot used is not uniform or when the map position of the datum point or objective is uncertain.

### USE OF THE WITNESS POINT.

**293.** When fire has been adjusted by aerial observation on an objective invisible from the ground, and when the map position is uncertain, the use of the witness point is resorted to.

**294. Definitions.**—A **witness point** is a point clearly visible on the ground, but not necessarily located accurately on the battle map (par. 95). It must satisfy the conditions of paragraph 299.

**295. The method.**—The method consists of two adjustments, one by aerial observation on the objective, and the other **simultaneously or immediately afterward** on the witness point.

The relation between the adjusted data for the witness point and the objective holds for subsequent firing on the objective. For such subsequent firing it is necessary only to readjust on the witness point and calculate the data for the objective.

Each double series of firing, the one on the witness point and the other on the objective, must be with the same kind and weight of projectile and with the same charge and powder lot; but between different double series these elements may be varied.

Another method is always to fire on the witness point with a projectile of lesser efficacy (semisteel shell, for example), and on the objective with long shell. In this case also the powder lot must be the same for each double series, but may be varied between different double series.

**296. Remark.**—The center of a series of 12 observed rounds on graze may be taken as a witness point, when several observation posts are available, each capable of accurate measurements with respect to such a point.

**297. Firing by means of a witness point.**—(*a*) Fill out a data sheet for the firing on both the objective and witness points, as if their map positions were accurately known.

Enter on the special data sheet for firing with a witness point the ratio $R=\frac{A}{a}$ of the approximate map ranges of the objective and the witness point.

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(*b*) With aerial observation adjust to include improvement fire on the objective.

(*c*) With any piece used as a **witness piece** (canon de référence), adjust simultaneously or immediately afterward on the witness point, to include improvement fire.

(*d*) Strip the two adjustments, using two ordinary data sheets.

**298.** (*a*) The stripped range of the objective, $A'$, and the stripped range of the witness point, $a'$, are thus determined.

If it is desired to fire again on the same objective, readjust on the witness point with the witness piece, filling out another ordinary data sheet for the firing on the witness point.

Enter on the special data sheet the new stripped range $a'_1$ of the witness point.

Take the difference $a'_1 - a'$.

(*b*) Determine the new stripped range of the objective by the following expression:

$$A'_1 = A' + R(a'_1 - a'),$$

R being defined in paragraph 297.

Proceed similarly for the deflection.

Beginning with the stripped deflections $\triangle'$ and $\delta'$ of the objective and witness point, respectively, calculate the new stripped deflection of the objective, $\triangle'_1$, corresponding to a new stripped deflection of the witness point, by the expression:

$$\triangle'_1 = \triangle' + (\delta'_1 - \delta').$$

**299. Conditions for the use of the witness point.**—The angular distance between the witness point and the objective should not exceed 300 mils (200 decigrades).

The ratio of ranges must be between 3–4 and 4–3.

**300. Remarks.**—If the ranges of the objective and the witness point are poorly known, the method may still be used.

Instead of using map ranges for determining R, the stripped adjusted ranges must be used. R is then replaced by R′. R′ is the ratio of the stripped range of the objective to that of the witness point, or $\frac{A'}{a'}$.

The remaining operations are as already described.

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| | |
|---|---|
| OBJECTIVE..... | Witness piece.....= |
| | rojectile, kind.....= |
| | ap range (a).....= |

| | NG ON WITNESS POINT. | |
|---|---|---|
| R | DEFLECTION. | |
| | | Wit. P. |
| Stripped range (A' | Stripped deflection (δ')..... | |

| | NG ON WITNESS POINT. | |
|---|---|---|
| R | DEFLECTIONS. | |
| Stripped range, cal | Deflection.<br>Stripped deflection (δ.) = | |

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# PART VI.

## AMMUNITION.


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## CHAPTER 1.

## H. E. SHELLS.

### KINDS.

**301.** The H. E. shells in service are:

I. The **steel shell** (OA) (obus en acier), which is classified into:

(*a*) **Point-fused** (amorçage de tête).—The long shells (obus allongés) of more than 3 calibers length, thin walls, and hence a large charge of explosive (between 20 and 30 per cent of the total weight of the shell).

(*b*) **Base-fused** (amorçage de culot).—Among these are:

(1) **Semiarmor piercing** (semi-A. P.) (obus de semirupture), which insures penetration in hard matériel without breaking. The percentage of explosive is generally about 10, but may be as low as 6.

(2) **Armor piercing** (A. P.) (obus de rupture), with a heavy ogive and thick wall, which insures penetration in very hard matériel. The percentage of explosive is very small. Its use is exceptional in land warfare.

**302.** II. **The cast-iron shell** (OF) (obus en fonte), which is generally of old model with thick walls, carrying only a small percentage of explosive (less than 10).

It is no longer manufactured.

**303.** III. The **semisteel shell** (OFA) (obus en fonte aciérée), made of a metal whose composition is between that of steel and cast iron.

This shell has come into use since the war began. Its properties are between those of the cast-iron shell and the long steel shell. Since it is cheaper and easier to manufacture than the long shell, it can replace the latter to a certain extent. It has a much thinner wall than the cast-iron shell, which permits a larger percentage of explosive (as high as 20).

The semisteel shell is generally point-fused. There are some base-fused types, for the attack of deep dugouts.



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**304.** IV. The **bomb,** for trench mortars.

The explosive is contained in a body of relatively thin sheet steel. This permits a high percentage of explosive (30 to 50), in spite of the relatively heavy tail.

The body is strong enough to penetrate earth, but it breaks on striking a hard substance.

**305. Shape of projectiles.**—To improve the ballistic qualities of shells and increase the maximum range, many recent designs have a tapered base (culot tronconique) and a double rotating band (D shell, of steel or semisteel, and B shell, of steel).

This design has limitations on account of the small explosive capacity as compared with the cylindrical type. For 155 shells, for example, the percentage of explosive is: Long, 24; steel B, 16.5; semisteel D, 10.5.

## FUSES.

**306.** The fuse in general (amorçage) includes all of the means for detonating the explosive in the projectile.

The fuse proper (fusée) causes the detonation of the charge of the shell by means of a primer (amorce) of fulminate of mercury surrounded by a **booster charge** of compressed explosive (explosif tassé).

The primer and booster charge may be combined in a single part, which, together with the relay (relai de feu) or relay and delay (retard), as the case may be, is called a **detonating booster** (détonateur). The detonating booster is placed in the **booster casing** (gaine) of the shell and held by the fuse.

The primer may be a part of the fuse, which is then called a **detonating fuse** (fusée détonateur). In this case, the booster charge is disposed around the walls and bottom of the booster casing, and forms a **booster** (gaine-relais); or placed in a **special booster cartridge** (cartouche spéciale) inserted in the booster casing.

**307.** Depending on its method of operation, the fuse or detonating fuse for H. E. shells is:

A. Percussion.

B. Time (fusante)[1] or combination (double effet).[2]

---

1 Fuses which are only time are for antiaircraft fire only. This means that the shell does not burst at all if the time element fails to function.

2 The MT fuse, Model 1916, for trench mortars, is a combination detonating fuse. It is normally a percussion fuse, but has a time safety device which causes it to act at the end of a certain fixed time if the percussion element fails.



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### A. PERCUSSION FUSES.

**308.** Percussion fuses are classed, according to the time interval between strike and burst, as:

1. Instantaneous.
2. Nondelay.
3. Delay.

#### 1. *Instantaneous fuzes.*

**309.** This class includes various fuzes developed since the war, which are extremely rapid in operation. The following are included:

(*a*) For shells with a booster of any model, or a 40-booster casing with a booster cartridge of 147 mm.

The percussion detonating fuses:

24/31 IA, Model 1915 } With uncolored head for right-hand rifling
24/31 IAL, Model 1916 } and red head for left-hand rifling.
24 IT, Model 1915 (for bombs).
24/31 RY, Model 1917.
24/31 I, Model 1914 (red head).

(*b*) For shells with a 30-booster casing or a series of booster casings.

The percussion detonating fuzes:

22/31 I, Model 1915 (red head).

**310.** For instantaneous functioning of these fuzes, the firing pin (rugueux) must be driven onto the primer by external means. Since they are point fuzes, the point of the shell must be the first part to reach the ground. Generally speaking, this requires an angle of impact greater than 10°.

For lesser angles, the I fuzes, Models 1914 and 1915, which will function by inertia, are still effective, but with results similar to those with a nondelay fuze (par. 311). The IA, IAL, IT and RY fuzes, which require an external blow on the firing pin, may give no-bursts.

If the angle of impact is sufficient:

(*a*) The I fuzes, Model 1914 or 1915, cause detonation the instant the ogive strikes the ground, giving a shallow crater with abrupt sides.[1]

[1] About 0 m. 30 to 0 m. 50 for the 75 H. E. shell.

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(*b*) The long fuzes (IA, IAL, or IT) cause detonation when the ogive is still above the ground. They make only a slight depression on the ground [1] which merges with the natural surface.

(*c*) The effects of the RY fuze are intermediate between those of the I and IA fuzes, but more like the latter.

The instantaneous fuzes give surface effects which make them particularly advantageous against:

Unsheltered personnel.

Matériel in the open.

Wire entanglements.

Such effects are generally greater with the long than with the short fuze.

The effects on the ground itself are insignificant,[2] particularly with the long fuze.

2. *Nondelay fuzes.*

**311.** The so-called nondelay fuzes have in reality a delay of about .01 second.

The following are included:

(*a*) For shells with a booster of any model, or a 40-booster casing with a booster cartridge of 147 mm.

The percussion detonating fuzes:

24/31, Model 1899, white head.

24/31, Model 1899–1915, SR, white head.

24/31, PR, Model 1916, non-delay.

(*b*) For shells with a 40-booster casing, Model 1895.

The percussion fuzes:

30 SM, Model 1878–1881.

30 SM, Model 1878–1881–M–1915, truncated head or cylindrical head, used with detonating boosters, Model 1895–M–1914, with delay removed and therefore acting as nondelay.

(*c*) For medium or large caliber shells, with point booster casing, Model 1915:

---

[1] About 0 m. 10 to 0 m. 15 for the 75 H. E. shell.

[2] However, trench mortar bombs, with long fuzes, have a detonation sufficiently powerful to knock down the revetments of trenches.

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The point detonating fuze, Model 1915, for medium or large caliber shells, with nondelay booster (tail of the fuze uncolored).

Since all of these fuzes function by inertia, they may be used in firing at all ranges.[1]

**312.** With a nondelay fuze, the shell travels a certain distance after striking before it bursts. Depending on the depth of penetration and the course taken by the shell underground, the burst may be at the surface, near it, or entirely underground. The crater has a corresponding depth. There is a reduction, which may be very considerable, of the effect on personnel, unsheltered matériel, or wire entanglements.

In firing against matériel obstacles, this fuze bursts shortly after traversing the first obstacle (as a wall or beam). Trench mortar bombs, however, having a low velocity, burst without much penetration when armed with nondelay fuzes.

### 3. *Delay fuzes.*

**313.** This class includes fuzes having a delay of more than 0.02 second. The delays at present standard are:[2]

| | | |
|---|---|---|
| 0.05 second short delay. | | |
| 0.15 second<br>0.25 second<br>0.35 second<br>0.50 second | long delay for | medium caliber shells.<br>large caliber shells.<br>370 and 400 shells.<br>520 shells. |
| 0.20 second for the normal delay of trench mortar bombs. | | |

[1] However, for angles of incidence around 1°, no-bursts must be expected, because the retardation of the projectile on striking is barely sufficient to operate the fuze. For this reason, shells fired against tanks are generally equipped with plates (plaquettes).

[2] The delays of individual fuzes may differ considerably from the standard value, which is the mean for a lot of fuzes.

According to the acceptance specifications of detonating fuzes, for the .05 second delay, delays between .03 second and .07 second are permitted; for the .15 second delay, the limits are .10 second and .24 second; for the .25 second delay, .17 second and .35 second; for the .35 second delay, .24 second and .45 second, and for the .20 second .10 second, and .30 second.

The specifications for the delay of boosters call for limits of .05 second to .15 second, and .25 second to .35 second for the .05 second and .25 second delays, respectively.

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**314.** Among the delay fuzes are:

(*a*) For shells with a booster of any model, or a 40-booster casing with a booster cartridge of 147 mm.

The percussion detonating fuzes:

24/31, model 1899–1908, 0.05 second delay.

24/31, model 1899–1915, CR, 0.05 second delay.

24/31, model 1899–1915, LR, 0.15 second delay.

24/31 PR, model 1916, 0.20 second delay.

24/31 BT, model 1916, 0.20 second delay.

The combination detonating fuse.

24 mm. MT, model 1916, 0.20 second delay.

(*b*) For shells with a 40-booster casing, model 1895.

The percussion fuzes:

SM, model 1873–1881.

30 SM, model 1878–1881–M–1915, with truncated head or cylindrical head, used with detonating boosters, model 1895–M–1904, with removable delay of 0.05 second (head of the delay in black), or of 0.25 second (head of the delay uncolored).

(*c*) For medium or large caliber shells, with point booster casing, model 1915.

The point detonating fuze, model 1915, for medium and large caliber shells, with booster of 0.25 second (tail of fuse varnished violet).

(*d*) For large caliber shells, with base booster casing, model 1915:

The base detonating fuze, model 1915, for large caliber shells, with booster of 0.25 second delay (tail of fuze varnished violet), of 0.35 second delay (tail of fuze varnished green), or of 0.50 second delay (tail of fuze varnished black).

(*e*) For base-fuzed shells, marine type, in which the flame is transmitted from the fuze to the explosive by a pellet of compressed powder with a delay of about 0.02 second.

**315.** The 0.05 second delay has been specially adopted for ricochet fire with the 75 gun. If the angle of impact is small (less than about 15°), the shell burrows more or less deeply in ricocheting. A short delay insures its bursting slightly above the ground, with good effect.

**316.** If the angle of impact is sufficient for the shell to bite, the short delay fuze permits medium or large caliber shells to be used against dugouts, if they are not too deeply buried.

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**317.** The other delays are used at high elevations according to the caliber of the shell, so as to permit the shell to penetrate to its full depth before detonating.

### B. TIME AND COMBINATION FUZES.

**318.** The only fuzes now in service permitting time shell fire are the detonating fuzes. They must be used with a booster or a 40-booster casing with a 147 mm. booster cartridge.

As far as the time system is concerned, they differ only in the maximum time of burning.

The 24/31 time detonating fuze, model 1915, the 24/31 combination detonating fuze, model 1915, and the 24/31 combination detonating fuze, model 1916, have a nominal maximum time of burning of 24 seconds.

The 24/31 A time detonating fuze, model 1916, has a nominal time of burning of 31 seconds.

The 24/31 LD combination detonating fuze, model 1917, has a nominal time of burning of 51 seconds.

**319.** For the 75, the actual time of burning differs but little from the nominal time for a muzzle velocity of 550 meters.

For other matériels, there may be an appreciable difference due to the muzzle velocity, the velocity of rotation, the maximum ordinate, and the exterior form of the projectile. For these reasons the firing tables give not only the time of flight but also the fuze setting for each range.

**320.** The percussion element of combination detonating fuzes is always with short delay.[1]

---

[1] This delay was adopted for consideration of safety. It would be very bad practice to use these fuzes for percussion fire, because they are more expensive and less rugged than percussion fuzes.

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## CHAPTER 2.

## SHRAPNEL AND CASE SHOT.

### KINDS.

**321.** The kinds of shrapnel and case shot in service are:

**322.** (1) The **shrapnel** (obus à balles), **old model** (120, 155, and 145), with a thick-walled **cast-iron** case, containing 18 gram ball (120) or 26 gram balls (other calibers), embedded in melted sulphur, with an ogival bursting charge of black powder.

**323.** (2) The **case shot** (obus à mitraille) (120 and 155), containing 20 gram balls (120) or 25 gram balls (155). The balls are lodged in recesses in cast-iron separators, which are held by a sheet-steel casing. The separators are broken up by the shock of discharge. A bursting charge of black powder is contained in the ogive. For the 155, a part of this charge is contained in a central tube extending entirely through the separators.

**324.** (3) The **base charge shrapnel** (65, 75, 155), having a base charge of black powder covered by a diaphragm, in front of which are 12 gram balls embedded in an inert substance.

**325.** (4) The **Robin shrapnel** (75, Model 97A),[1] containing 12 gram balls throughout its length. At the base, the successive layers of balls are embedded in black powder; in front of this, in a mixture of powder and saltpeter. Toward the forward end, the mixture becomes richer in saltpeter, until at the point, it is entirely the latter.

**326.** The base charge and Robin shrapnel have a steel case, which is not ruptured by the action of the bursting charge. They thus act as small guns. The base charge propels the balls forward with an increase of velocity of about 100 meters over the remaining velocity of the projectile at the instant of burst. The balls rapidly lose their velocity, because of their form and small weight.

The cast-iron shrapnel and case shot have the bursting charge in the ogive. The action of the bursting charge therefore causes a

[1] The 75 shrapnel with a special ogive for antiaircraft firing is of the Robin type.



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slight loss of velocity. In addition, the axial charge of the 155 case shot spreads the balls. The balls and fragments, however, retain their velocity better than with the base charge and Robin shrapnel, because of their greater weight.

### FUZES.

**327.** Shrapnel and case shot are armed with a fuze so constructed as to burst the projectile at the desired instant.

This fuze is:

**Time,** or
**Combination,**

depending on its method of operation.

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## CHAPTER 3.

## GAS SHELLS.

### KINDS.

**328.** The gas shells of the A. E. F. are classed according to the properties of the liquid charge as:

Lethal.

Persistent or lachrymatory.

Some gases are both lethal and persistent.

**329.** Lethal (deadly) gas is used to produce casualties. In most cases, one or two full breaths is sufficient to produce a severe casualty. The enemy mask, if adjusted in time, gives more or less complete protection, depending on the nature of the gas.

Persistent gases are only slightly lethal, but extremely lachrymatory or irritating.

**330. Design of projectiles.**—The projectiles are steel or semisteel shell, or bombs. The projectile is merely a container, no effect from the fragments being expected. Existing types are utilized for simplicity, economy, and rapidity of production.

Gas shells are made the same weight as the corresponding H. E. shells by filling the cavity only partially, or by combining liquids of different specific gravities. A void is always left to allow for expansion of the liquid.

**331. Marking of gas shells.**—The following system is used in marking gas shells:

**Lethal.—White** bands, ½ inch wide and ½ inch apart, around the middle of the shell body, which is painted gray.

**Persistent.—Red** bands of the same kind.

In addition all gas shells are stenciled in white lengthwise of the body with the words, "Special Gas."



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The following distinctive markings apply to the gas shells now supplied:

| FILLING. | BANDS. |
|---|---|
| V. N. | 1 white. |
| C. G. | 2 white. |
| N. C. (P. S. and K. J.). | 1 white, 1 red. |
| P. G. (P. S. and C. G.). | 1 white, 1 red, 1 white. |
| B. A. | 1 red. |

The character of the liquid charges is described in paragraphs 383, et seq.

**332. Fuzes.**—The explosive charge necessary to rupture a gas shell is contained in the booster casing. The charge is variable according to whether it is desired to vaporize the liquid and form a gas cloud at once, or spray the liquid over the ground for the production of gas by evaporation.

**333. To secure the maximum effectiveness, lethal and persistent gas shells must be used with instantaneous fuzes.**—A nondelay fuze bursts the shell after it has penetrated the ground. A portion of the liquid is thus absorbed by the earth and the efficiency of the shell diminished. A burst much above the ground is undesirable.

Either the instantaneous or the long fuze is used.

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## CHAPTER 4.

## OTHER SPECIAL SHELLS.

### ADJUSTING SHELLS (Projectiles de réglage).

**334.** These are now in use only for the calibers of 105 and 120.

The visibility of the burst is improved by pieces of phosphorus in the base.

They are distinguished by a white band on the body of the shell and the letters Reg-Ph.

Adjusting shells for the other calibers are being developed.

They should be armed with an instantaneous or nondelay fuze.

### SMOKE SHELLS (Projectiles fumigènes).

**335.** These are used to screen an attack from observation, or to blind hostile organizations. They may be mixed with a barrage to improve its screening effect.

Smoke shells are distinguished by one yellow band on a gray body and the stenciled words "Special Smoke."

They should be armed with an instantaneous or nondelay fuze.

### STAR SHELLS (Obus éclairants).

**336.** These are for the study of objectives or watching the terrain at night.

They contain one or several parachute stars, which are released by the burst.

The illumination reaches several hundred meters and lasts about a minute.

This shell is at present manufactured only for the 75.[1] It is armed with 22/31A time fuse, Model 1917 (maximum time of burning, 31 seconds).

---

[1] There are still some 155 star shells in the supply of fortified places.



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### TRACER SHELLS (Obus traceurs).

**337.** There are tracer shells for the 75 and 105 calibers for attacking balloons.

During flight the shell emits long flames and smoke from vents in the ogive. This materializes the trajectory. The shell is incendiary and ignites the gas of balloons struck by it.

It is visible only during flight, but as the trajectory is outlined the adjustment of fire is quite easy.

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# PART VII.

## EFFECT OF PROJECTILES.


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# CHAPTER 1.

## H. E. SHELL.

### PENETRATION.

**338.** The effect of an H. E. shell bursting on graze depends essentially on its course after impact and where on this course the burst occurs.

The course after impact depends on several elements: Angle of impact, remaining velocity, form and weight of the shell, whether it is flying true, the nature of the ground. The angle of impact is the most important of these elements.

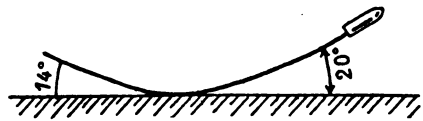


FIG. 43.

**339.** The following are the typical cases of the course of the shell after impact, depending on the value of the angle of impact.[1]

**Flat fire** (Tir tendu).—$\omega$ from 0° to 15°.

The shell ricochets, leaving only a slight trace on the ground (fig. 43).

**Flat fire.**—$\omega$ from 15° to 25°.

Depending on the remaining velocity and the sharpness of the point, the shell ricochets after a certain distance underground ([2]), or remains a small distance underground (fig. 44).

[1] The angle of fall may be taken as 3/2 of the elevation for guns with normal charge (pleine charge) and as 5/4 of the elevation for howitzers and mortars.

[2] Shells with a tapered base have a greater tendency to ricochet than those with a cylindrical base. The ogive of semisteel shells is frquently broken by impact. A no-burst results if the ogive separates from the body before the fuze functions.



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**340. Curved fire** (tir plongeant).—$\omega$ from 25° to 40°.

The shell follows a sinuous course underground, tending to return to the surface. However, if the shell is much flattened on the point

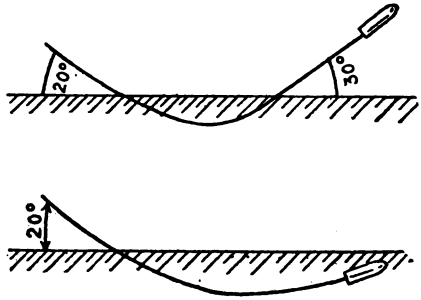


FIG. 44.

(P shell, called a truncated ogive shell, capped with a thin plate), the course underground is practically straight and in prolongation of the trajectory regardless of the angle of impact (fig. 46).

**341. High angle fire** (tir vertical).—$\omega$ greater than 40°.

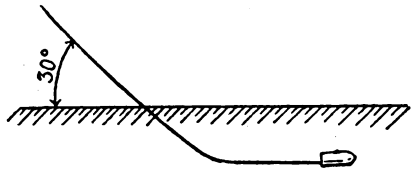


FIG. 45.

The course of the shell underground is practically straight. The penetration depends on the remaining velocity of the shell, its shape and weight, and on the condition and nature of the ground (fig. 47).

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**342.** The penetration of the shell is affected by so many elements that fixed values for it can not be given. It varies with the nature of the ground and the obstacles encountered, but especially with the caliber of the shell and the remaining velocity.

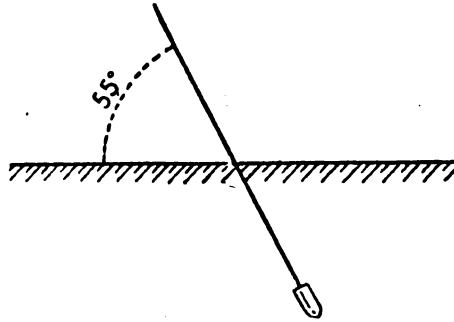


FIG. 46.

**343.** The following table gives some experimental results, using dummy projectiles:[1]

| Caliber. | Remaining velocity. | Angle of impact. | Mean vertical penetration. | Mean horizontal penetration. |
|---|---|---|---|---|
| | *Meters.* | *Degrees.* | *Meters.* | *Meters.* |
| 75 | 220 | 25 | 1.0 | 1.5 |
| 155 | 280 | 30 | 1.6 | 2.5 |
| 220 | 225 | 42 | 2.0 | 4.0 |
| 280 | 350 | 38 | 3.4 | 4.5 |
| | 350 | 65 | 4.5 | 3.8 |
| | 250 | 35 | 3.0 | 6.5 |
| 370 | 290 | 50 | 5.0 | 5.0 |
| | 290 | 65 | 6.0 | 2.5 |

[1] The ground was of medium resistance, a calcareous tufa covered with about .60 meters of clay.

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**344.** From the preceding, it can be seen that deep penetrations can be obtained only with large caliber shells fired at high elevations.

For a penetration of 2 meters in medium soil it is necessary to use at least a 155 shell, with an angle of impact not less than 45°.

For the medium calibers, up to 155, inclusive, at elevations less than 20°, no more than 1 or 1½ meters penetration can be expected.

**345. Concrete.**—Penetration in **concrete** (béton) or **reinforced concrete** (béton armé) varies greatly with the quality of the matériel, but is always much less than in earth. It is principally a question of the striking energy, so that high remaining velocities and large calibers are necessary. It is also essential that the shell be not broken by the impact, which necessitates a semi-A. P. shell with a heavy hardened point and a delay base fuze.

## EFFECT OF THE INDIVIDUAL BURST.

### A. Sheaf of the burst.

**346.** If an H. E. shell is detonated at rest, the fragments are thrown practically perpendicularly.

Three sheafs are thus formed:

**Ogive sheaf** (gerbe d'ogive), not dense, to the front.

**Lateral sheaf** (gerbe latérale), the most important, consisting of a thin sheet, perpendicular to the axis of the shell.

**Base sheaf** (gerbe de culot), to the rear.

Figure 47 illustrates these effects.

**347.** If the shell bursts in flight, the character of the sheafs is the same, but the velocity and direction of the fragments is the resultant of the velocity of the shell and the velocity due to the burst.

As the axis of the shell practically coincides with the trajectory, the lateral sheaf is approximately perpendicular to the trajectory.

If the angle of impact is not too great nor the burst too high, the trace of the lateral sheaf is clearly visible on the ground, and is called by the French the "coup de hache" (cut of an axe).

With high angle fire and an instantaneous fuze, the ground is swept in all directions.

**348.** The burst of a **steel shell,** particularly the long one, breaks the body into splinters or sharp fragments (éclats).

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The initial velocity imparted to these fragments is around 1,000 to 1,500 meters.

The three sheafs are clearly separated.

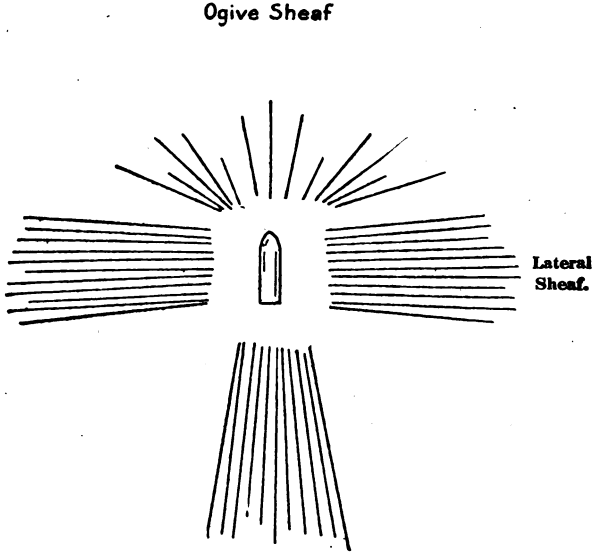


FIG. 47.

On account of their irregular form, the fragments lose their velocity very quickly. The small ones are usually thrown not farther than about 30 meters. The large ones may travel several hundred meters.

**349.** The three sheafs of the **semisteel shell** are less distinct than with the steel shell.

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The fragments are smaller and more numerous.

The semisteel shell is therefore more efficient than the long shell against unsheltered personnel, close to the burst, in spite of its lesser bursting charge.

But the radius of effect of the semisteel shell is considerably less than that of the steel shell, because of the small size of the fragments and their lesser velocity.

**350.** The burst of the **cast-iron shell** more or less pulverizes the metal, although there are occasional large fragments with low velocity.

The radius of effect of these shells is very small.

### B. Shell gas.

**351.** The detonation of an H. E. shell creates a mass of gas whose quantity is proportional to the explosive charge.

When the burst is in air, the blast of the gas of explosion is very powerful.

**352.** A shell bursting in a closed place has a particularly violent effect. The walls are generally forced outward; if not, the gas escapes with destructive violence through the openings.

**353.** If the shell bursts underground or in an obstacle the expansion of the gases causes a considerable disturbance and upheaval if the effect reaches the surface. If the effect is entirely underground, a cavity is formed, and nearby dugouts are crushed in.

**354.** Shell gases are very poisonous. By filtering through fissures in the ground, they can reach dugouts which are still intact and cause death, unless good ventilation is maintained.

H. E. shells are not generally incendiary.

### C. Variation of the effect with the position of the burst.

**355.** (1) **In air.**—The shell can burst in air in time or ricochet fire. Most of the effect is from the fragments.

For a given shell, the effect varies with the height of burst, but is nearly independent of the range.

If the burst is very near the ground, nearly all of the fragments will be effective, but the efficiency of the burst will be small because it is too local.

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If the burst is too high, the fragments will lose their effectiveness before reaching the ground, except a few large ones in the case of the steel shell.

**356. Time shell fire.**—With the 75, 105, 120, and 155 H. E. shells, steel or semisteel, the best height of burst is between 10 and 20 meters.

The following table gives the depth and width of the ground effectively covered by the fragments of a burst, and the maximum distance effectively reached by the largest fragments:

| Shell. | Zone effectively covered. | | Radius of effectiveness of the largest fragments. |
|---|---|---|---|
| | Depth. | Width. | |
| | *Meters.* | *Meters.* | *Meters.* |
| 75, Model 1900, steel | 5 | 15 | 150 |
| 105, Model 1915, steel | 6 | 45 | 300 |
| 120, Model 1914, steel | 8 | 50 | 300 |
| 120, Model 1915, semisteel | 9 | 45 | 100 |
| 155, Model 1914, steel | 8 | 70 | 500 |
| 155, Model 1915, semisteel | 13 | 70 | 200 |

The efficacy varies but little for heights between 5 and 30 meters, but decreases rapidly above 30 meters. At 80 meters height there is practically no effect, only a few large fragments being effective.

**357.** When the height of burst is about 20 meters, the semisteel is more effective than the steel shell, as it gives more deadly fragments in the space effectively covered. Moreover many of the fragments which are not deadly give important superficial effects. The semisteel is therefore preferable.

**358.** The height of burst adjustment is very important in time shell fire. The range must also be accurately adjusted, as the lateral sheaf has very little depth.

**359.** If the adjustment is correct, time shell fire has important moral and material effect on unsheltered personnel (in the open or in open trenches).

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It is not effective against matériel, because the bursts are too high.

At long range, the fuze dispersion is such that, for a burst height of 20 meters, both grazes and very high bursts will be obtained. Such fire will be much less effective than at mean ranges and percussion fire with long fuzes is better.

**360.** Moreover, in general, time shell fire should be used only when ricochet fire and percussion fire with instantaneous fuzes can not be used. Time fire, shell or shrapnel, is appropriate in the following cases:

(*a*) When the ground at the point of fall is badly torn up (craters or shell holes), or marshy.

(*b*) When the objective can not be reached because of its defilade.

Time fire is particularly appropriate when the objective is on such a steep slope that percussion fire with instantaneous fuzes is not effective.

**361. Ricochet fire.**—The H. E. shell, bursting after ricochet is similar to an air burst in time fire.

But the burst is on an ascending trajectory whose direction is frequently deviated by contact with the ground. The **base** sheaf is effective. The **lateral** sheaf has variable inclinations in the plane of fire. This is in reality favorable, because of the small depth covered by a single burst.

The proportion of ricochets increases as the angle of impact decreases.

**362.** The following table shows the ranges between which ricochet fire may be used with the 75 H. E. shell, Model 1900, normal charge, for various slopes of the ground at the objective:

| | Reverse slope. | | | | Forward slope. | | | |
|---|---|---|---|---|---|---|---|---|
| Slope..... | 20% | 15% | 10% | 5% | 5% | 10% | 15% | 20% |
| Range meters... | 3,800 to 5,900 | 3,500 to 5,600 | 2,600 to 5,300 | 1,700 to 4,700 | 500 to 4,000 | 500 to 3,000 | 500 to 2,600 | 500 to 1,600 |

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As a general rule, it may be taken that the 75 shell with normal charge will ricochet when the angle of incidence is less than 15°.

With the fuse of 0.05 second delay, it acts as a low air burst, at a mean height of 2 to 4 meters and about 15 meters beyond the point of impact.

**363.** Ricochet shell fire is effective against matériel within a meter of the burst. Against **personnel,** the effect is about the same as with air bursts in time fire, but slightly greater because the base sheaf is more effective.

**364.** There are the following difficulties in connection with ricochet shell fire with medium calibers:

(*a*) Before ricocheting, medium caliber shells travel considerably further in the ground than the 75 shells. The 0.05 second delay fuze, Model 1899–1908, has thus an insufficient delay for ricochet fire, for most ground and average fighting ranges.

(*b*) Semisteel shells are frequently broken by impact at small angles of impact which lessens the proportion of ricochets.

(*c*) For small angles of impact, the greater the weight of the shell and the remaining velocity, the greater the likelihood of deforming the fuze and causing a no-burst.

In general, if ricochet fire with medium caliber shells is necessary, use percussion detonating fuzes with 0.15 second delay, and carefully observe the bursts. If there are too many no-bursts, the fire should be stopped.

With the 105 steel shell, ricochet fire with long delay fuzes can be used over level ground up to about 7,000 meters.

**365.** (2) **At the ground.**—For all ranges having angles of impact greater than about 10°, bursts at the ground can be obtained with instantaneous fuzes.

Because of the low burst, the effects of the fragments are somewhat less than for the air burst, but with the same characteristic effect of the lateral sheaf, particularly with long fuzes. The only fragments found in the crater are a few from the ogive and fuze.

For high elevations (high angle howitzer fire and trench mortar fire), the lateral sheaf sweeps all around the point of burst.

Fire with instantaneous fuzes is very effective against **personnel in the open,** in which case, as in time fire, the semisteel shell is preferable.

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**366.** Up to a certain radius, the effect of the blast augments that of the fragments in sweeping the ground.

Long shells and bombs with the instantaneous fuze are also very effective in destroying entangelements when the range is great enough.

With matériel using several charges, fire with instantaneous fuzes should be with the smallest charge giving the necessary range.

**367.** (3) **Slightly underground.**—Bursts slightly underground are obtained—

(*a*) With nondelay fuzes, at all elevations which do not give ricochets.

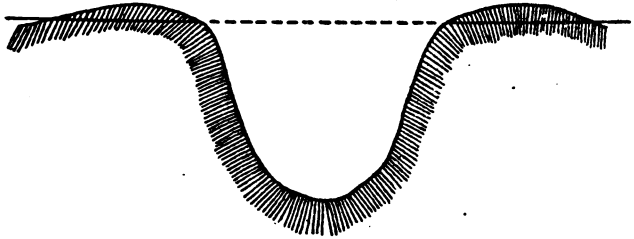

FIG. 48.—Clean crater (entonnoir déblayé).

(*b*) With delay fuze, and angles of impact less than about 25°, when ricochets do not result.

**368.** A shell bursting at a depth of once or twice its length forms a hemispherical crater, throwing earth and fragments to some distance but leaving some fragments in the crater.

The effect depends on the ground and the explosive. For a given explosive the effect is proportional to the bursting charge.

**369.** The following table gives the dimensions of some clean craters in very hard undisturbed ground (chalky or calcareous soil or gravel). It will be seen that even with medium calibers up to include 220 the shell can not penetrate more than about a meter and completely clear the crater:

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| Shell. | Crater. | | |
|---|---|---|---|
| | Diameter. | Depth. | Volume. |
| | *Meters.* | *Meters.* | *Cubic meters.* |
| 120 long | 2.5 | 0.9 | 2.6 |
| 155 long | 3.5 | 1.1 | 6.0 |
| 220 long | 4.5 | 1.4 | 13.3 |
| 370 long | 6.0 | 2.2 | 36.0 |

In clay, the volume of earth thrown out may be as high as double these figures.

In earth, previously loosened, the excavation may be triple that stated above.

**370.** Although fired at high elevations and with long delay fuzes, trench mortar bombs do not penetrate deeply and therefore form clean craters.

| Mortar. | Bomb. | Crater. | |
|---|---|---|---|
| | | Diameter. | Depth. |
| | | *Meters.* | *Meters.* |
| 58 No. 2, or Van Deuren | LS, 18 kg | 2 to 3 | 1 to 1.5 |
| | DLS, 35 kg | 4 to 4.5 | 1.75 |
| 150 T | 18 kg | 3 to 3.5 | 1.5 to 1.8 |
| 240 long or short | 87 kg | 6 to 10 | 1.3 to 3 |

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**371.** (4) **At a depth of 3 or 4 shell lengths.**—As the depth at which the shell bursts increases, the amount of earth displaced increases, but a part falls back into the crater and covers the bottom. Such effects are obtained particularly with delay fuzes at elevations between 25° and 40°.

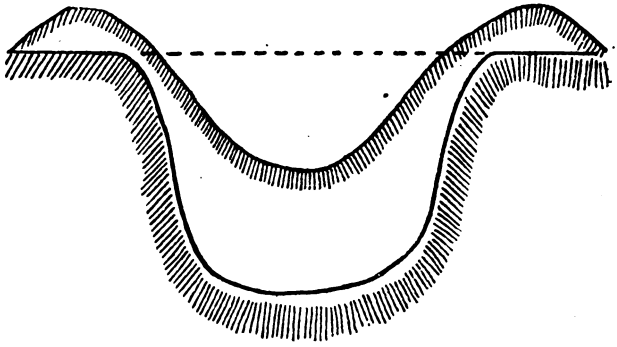

FIG. 49.—Earth loosened.

The following table shows, for hard soil, the amount of earth loosened for various long shells:

*Earth loosened.*

| Shell. | Outer diameter. | Depth. |
|---|---|---|
| | *Meters.* | *Meters.* |
| 155 long | 3.5 | 1.5 |
| 220 long | 5.5 | 2.3 |
| 270 long | 6.0 | 3.0 |
| 370 long | 10.0 | 6.0 |

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**372.** (5) **At great depth.**—When the burst occurs at too great a depth the force of explosion is no longer sufficient to rupture the ground above the point of burst.

A subterranean cavity is formed, the surface of the ground being slightly raised over the burst, with sometimes a circular depression around the raised portion.

A cavity thus formed is called a **camouflet.**

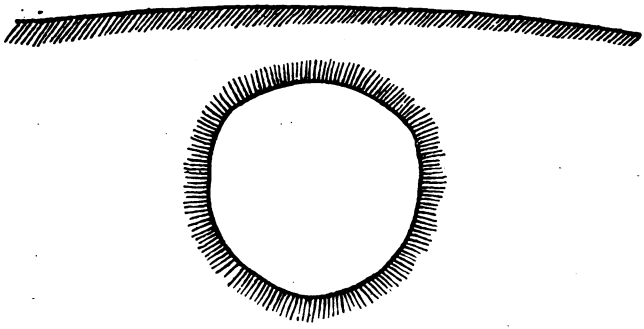

FIG. 50.—Camouflet.

The force of the explosion is spent by violent pressure on the surrounding earth. The camouflet will thus have from 1 to 2 meters greater depth than the penetration of the shell.

The effect is entirely underground. It may reach deep dugouts if the shell is large enough. No fragments come out of the ground. If any smoke escapes it is very thin and the observation of the shot is generally impossible.[1]

Camouflets occur principally in high angle fire and sometimes in firing at elevations of about 40°.

[1] Observation must be obtained by occasional rounds with the same shell but using a nondelay fuze.

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**373.** The following table gives the approximate depth of the bottom of camouflets in high angle fire, at the usual fighting ranges, in hard ground. The gas pressure is felt at some distance and may break down dugouts below the camouflet:

| Shell. | Depth reached. |
|---|---|
| | *Meters.* |
| 155 long | 3.0 |
| 220 long | 4.5 |
| 270 long | 6.0 |
| 370 long | 10.0 |

The depth reached is materially modified by the nature of the soil and the remaining velocity.

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## CHAPTER 2.

## SHRAPNEL AND CASE SHOT.

### EFFECT OF THE INDIVIDUAL BURST.

#### A. Air.

**374.** When a shrapnel bursts in air, the balls are driven forward and form the **shrapnel cone** (gerbe). The distribution of the balls over a right section of this cone may be taken as uniform.

The angle at the apex of the shrapnel cone is called the **angle of opening** (ouverture de la gerbe). Its value, or half its value, is given in the firing tables.

The axis of the cone is substantially tangent to the trajectory at the point of burst.

The ground covered by the shrapnel balls is called the **pattern.** Its form varies with the range, and its size for a given range increases with the height of burst.

**375.** Shrapnel balls lose their velocity and penetration rapidly because of the air resistance and after a short flight cease to be effective.

To be effective a shrapnel burst must be low, but if too low the pattern is small and its effectiveness much reduced.

**376. It is therefore very important that the bursts in fire for effect be adjusted at the normal height.**—The permissible departure from the normal height of burst without losing too much effectiveness is smaller with the lighter balls. In night firing, it is generally difficult to control the height of burst. In this case, the heavy balls of 18 to 26 grams (120, 155, 140 and 145 shrapnel or case shot), are better than 12 gram balls (65, 75, and 105 base charge shrapnel or 75 Robin shrapnel).[1]

[1] If the height of burst is well adjusted, the 155 shrapnel or case shot is very effective, because of the size and weight of the balls and the separator fragments of the latter projectile. In close defense, the ground is effectively covered to a range of about 600 meters for a fuse setting of 0.



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**377. Time shrapnel fire is the most effective method against personnel in the open. It is particularly appropriate to prevent repair of demolitions and for harassing and interdiction fire.**—It may be used for barrage and it gives sure effect against machine guns in shell holes outside of the trenches.

**378.** But against sheltered personnel, even with high angle fire and a well adjusted height of burst, time shrapnel or case shot fire is practically without effect.

The balls or separator fragments are nearly always stopped by a light cover, such as a brush roof covered with 10 cm. of earth and 5 cm. planks.

At long range the fuze and range dispersion is so considerable that time shrapnel fire should be used only against large bodies of troops in the open.

### B. Graze.

**379.** When a shrapnel bursts on graze, at a small angle of impact, it ricochets before the burst actually occurs.

The cone of a shrapnel bursting after ricochet sweeps the ground very effectively for short ranges.[1] As the range increases, the trajectory after ricochet becomes more elevated, the balls are projected into the air, and lose their effectiveness before reaching the ground.

Unless there is ricochet, percussion shrapnel is ineffective.

It is not advisable to use shrapnel against matériel, even in the open.

**380. Incendiary effect.**—Percussion or low air bursts of shrapnel or case shot, when close to combustible matériel, can have incendiary effects. The Robin shrapnel is especially effective in this respect.

---

[1] With the 75, up to 1,500 meters, on ground favorable for ricochets, the effectiveness of percussion shrapnel fire against unsheltered personnel is practically the same as that of time fire. The ground effectively covered extends 200 meters beyond the point of fall. Under these conditions, the adjustment of the height of burst is eliminated and there is a lesser dispersion than in time fire.

120 or 155 shrapnel or case shot fired so as to burst on graze about 100 meters *from the pieces* are effective up to about 500 meters.

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## CHAPTER 3.

## GAS SHELLS.

**381.** The effect of gas shells is derived from the vaporization of the liquid charge. Casualties are not to be expected from the shock of burst or from the fragments.

The liquid is wholly or partially vaporized when the shell bursts. In the case of the less volatile liquids, the vaporization may not be complete for as long as five days.

### USE.

**382.** Atmospheric conditions materially influence the effectiveness of lethal and persistent gases.

The wind rapidly dissipates a gas cloud and hastens the vaporization of liquid scattered on the ground. A drop in temperature lowers the dew point, and a rise in temperature expands the gas and hastens its diffusion. Sunshine causes local ascending air currents which lift the gas above the ground. Water destroys the gas products by chemical action. Water vapor, however, has no appreciable effect. A heavy rain is very detrimental.

In general lethal gases should not be used when the wind velocity is over 3 meters. Persistent gases may be used with wind velocities up to 6 meters. But the effectiveness of all gas shells is greatly reduced by a strong wind.

Since all of the gases used are heavier than air, they tend to flow into valleys and depressions. Their effects are greatest in places that are sheltered from the wind, such as woods, valleys, closely built villages, or ground covered with thick brush.

**383. Characteristics of gases.**—The liquid charges of the gas shells used by the A. E. F., at present, are as follows:

**V. N.—1 white band.** A mixture of 4 different liquids. The lethal part is lighter than air, but is held down to some extent by the other gases. The vapor is very lethal and in high concentrations causes death, but when breathed in lower concentrations produces no harmful effects.

**C. G.—2 white bands.** This is probably the most important gas. The liquid has a boiling point of 8° C., and the vapor is several times heavier than air. It is not only fatal in high concentrations, but



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produces serious casualties if breathed for a sufficient time in lower concentrations. The effect may last from a minimum of five minutes in the open, with a 3-meter wind, to six hours or more in places sheltered from the wind.

**N. C.—1 white, 1 red band.** This is a mixture of P. S. and K. G., which boils at 112° C. The vapor is many times heavier than air. It is a persistent lachrymator, and, in addition, is quite lethal. Its vapors penetrate the German mask to a greater extent than any other, so that it may profitably be used simultaneously with C. G. for destruction. It lasts from one-half hour to 18 hours.

**P. G.—1 white, 1 red, 1 white band.** This is a mixture of P. S. and C. G. The vapor is several times heavier than air. It is lachrymatory and quite lethal. It penetrates the German mask, causes vomiting, and forces the removal of the mask. It is used for destruction.

**B. A.—1 red band.** The vapor is several times heavier than air and is intensely lachrymatory. It is effective in concentrations as low as one part in a million. In high concentrations it is fairly lethal, and is very economical for neutralizing. Its effect lasts from 2 to 48 hours.

### CONDITIONS FOR SAFETY.

**384.** The respirator gives complete protection against all of these gases when it is in good condition and well adjusted. The French M-2 mask gives complete protection, except in the case of N. C., P. G., and B. A., for which it affords partial protection.

**385. Persistence of gases.**—(*a*) In the open with a wind of 2 meters or more:

| | |
|---|---|
| V. N | 10 minutes. |
| C. G | 20 minutes. |
| B. A | 40 minutes. |
| P. S. or P. G | 2 to 3 hours. |
| N. C | 3 to 4 hours. |

(*b*) In woods or brush:

| | |
|---|---|
| V. N | 1 hour. |
| C. G | 3 hours. |
| B. A | 4 to 5 hours. |
| P. S. or P. G | 5 to 6 hours. |
| N. C | 8 to 10 hours. |

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(c) In the case of unprotected dugouts, cellars, or deep holes, the time may be considerably longer. In the case of certain gases, it is unsafe to dig up the ground where a shell has burst for a week or more.

These figures must be taken into consideration in gas-shell firing on ground over which our infantry is to attack.

**386. Safe distance of gas-shell objectives from friendly line.**—Gas should never be fired on an objective which is less than 200 meters from the friendly line, even when the wind is toward the enemy. When the wind is blowing toward the friendly line, the minimum safe distances, without masks, are as follows:

| | Meters. |
|---|---|
| V. N. | 500 |
| C. G. | 1,000 |
| N. C., P. G., B. A. | 2,500 |

When the objective is less than these distances from the friendly line, our infantry should be warned [1] to put on its masks, if the wind and terrain are such that the gas may drift toward them. If such warning is not practicable, gas shell should not be fired under these conditions.

**387. Storage of gas shells.**—At the battery positions, gas shells should be piled in small dumps, the number in each being as follows:

| | |
|---|---|
| The 75 | 100 |
| The 120 | 50 |
| The 155 | 25 |

Leaking gas shells should be disposed of by firing, if practicable, otherwise by burying them at least 2 meters. Dumps should be located to the leeward of battery positions, according to the prevailing wind.

A hostile shell striking a dump has never resulted fatally in service. The liquid is not perfectly vaporized and the gas cloud formed is inconsiderable.

---

[1] Since gas-shell firing should always be by surprise, telephone conversation in regard to it must be in code, to prevent the enemy from learning of it. Communications of this kind should be reduced to a minimum.

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# APPENDICES



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# APPENDIX 1.

## CONVERSION TABLES

FOR

## ANGULAR UNITS


TABLE I. *Degrees*, *minutes*, and *seconds* into *grades*.
TABLE II. *Grades* into *degrees* and *minutes*.
TABLE III. *Centigrades* into *minutes* and *seconds*.
TABLE IV. *Decimilligrades* into *seconds*.
TABLE V. *Minutes* and *seconds* into *thousandths* of a *degree*.
TABLE VI. *Degrees* into *mils* (6400).
TABLE VII. *Grades* into *mils*.


## TABLES OF METRIC EQUIVALENTS.


TABLE I. *Linear equivalents*.
TABLE II. *Volume* and *capacity equivalents*.
TABLE III. *Area equivalents*.
TABLE IV. *Weight equivalents*.
TABLE V. *Approximate metric equivalents*.




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TABLE I.—*For converting degrees, minutes, and seconds into grades.*

| Degrees. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | (1) | 1.1 | 2.2 | 3.3 | 4.4 | 5.5 | 6.6 | 7.7 | 8.8 | 10.0 |
| 1 | 11.1 | 12.2 | 13.3 | 14.4 | 15.5 | 16.6 | 17.7 | 18.8 | 20.0 | 21.1 |
| 2 | 22.2 | 23.3 | 24.4 | 25.5 | 26.6 | 27.7 | 28.8 | 30.0 | 31.1 | 32.2 |
| 3 | 33.3 | 34.4 | 35.5 | 36.6 | 37.7 | 38.8 | 40.0 | 41.1 | 42.2 | 43.3 |
| 4 | 44 4 | 45.5 | 46.6 | 47.7 | 48.8 | 50.0 | 51.1 | 52.2 | 53.3 | 54.4 |
| 5 | 55.5 | 56.6 | 57.7 | 58.8 | 60.0 | 61.1 | 62.2 | 63.3 | 64.4 | 65.5 |
| 6 | 66.6 | 67.7 | 68.8 | 70.0 | 71.1 | 72.2 | 73.3 | 74.4 | 75.5 | 76.6 |
| 7 | 77.7 | 78.8 | 80.0 | 81.1 | 82.2 | 83.3 | 84.4 | 85.5 | 86.6 | 87.7 |
| 8 | 88.8 | 90.0 | 91.1 | 92.2 | 93.3 | 94.4 | 95.5 | 96.6 | 97.7 | 98.8 |
| 9 | 100.0 | 101.1 | 102.2 | 103.3 | 104.4 | 105.5 | 106.6 | 107.7 | 108.8 | 110.0 |
| 10 | 111.1 | 112.2 | 113.3 | 114.4 | 115.5 | 116.6 | 117.7 | 118.8 | 120.0 | 121.1 |
| 11 | 122.2 | 123.3 | 124.4 | 125.5 | 126.6 | 127.7 | 128.8 | 130.0 | 131.1 | 132.2 |
| 12 | 133.3 | 134.4 | 135.5 | 136.6 | 137.7 | 138.8 | 140.0 | 141.1 | 142.2 | 143.3 |
| 13 | 144.4 | 145.5 | 146.6 | 147.7 | 148.8 | 150.0 | 151.1 | 152.2 | 153.3 | 154.4 |
| 14 | 155.5 | 156.6 | 157.7 | 158.8 | 160.0 | 161.1 | 162.2 | 163.3 | 164.4 | 165.5 |
| 15 | 166.6 | 167.7 | 168.8 | 170.0 | 171.1 | 172.2 | 173.3 | 174.4 | 175.5 | 176.6 |
| 16 | 177.7 | 178.8 | 180.0 | 181.1 | 182.2 | 183.3 | 184.4 | 185.5 | 186.6 | 187.7 |
| 17 | 188.8 | 190.0 | 191.1 | 192.2 | 193.3 | 194.4 | 195.5 | 196.6 | 197.7 | 198.8 |
| 18 | 200.0 | 201.1 | 202.2 | 203.3 | 204.4 | 205.5 | 206.6 | 207.7 | 208.8 | 210.0 |
| 19 | 211.1 | 212.2 | 213.3 | 214.4 | 215.5 | 216.6 | 217.7 | 218.8 | 220.0 | 221.1 |
| 20 | 222.2 | 223.3 | 224.4 | 225.5 | 226.6 | 227.7 | 228.8 | 230.0 | 231.1 | 232.2 |
| 21 | 233.3 | 234.4 | 235.5 | 236.6 | 237.7 | 238.8 | 240.0 | 241.1 | 242.2 | 243.3 |
| 22 | 244.4 | 245.5 | 246 6 | 247.7 | 248.8 | 250.0 | 251.1 | 252.2 | 253.3 | 254.4 |
| 23 | 255.5 | 256.6 | 257.7 | 258.8 | 260.0 | 261.1 | 262.2 | 263.3 | 264.4 | 265.5 |
| 24 | 266.6 | 267.7 | 268.8 | 270.0 | 271.1 | 272.2 | 273.3 | 274.4 | 275.5 | 276.6 |
| 25 | 277.7 | 278.8 | 280.0 | 281.1 | 282.2 | 283.3 | 284.4 | 285.5 | 286.6 | 287.7 |
| 26 | 288.8 | 290.0 | 291.1 | 292.2 | 293.3 | 294.4 | 295.5 | 296.6 | 297.7 | 298.8 |

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| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 27 | 300. 0 | 301. 1 | 302. 2 | 303. 3 | 304. 4 | 305. 5 | 306. 6 | 307. 7 | 308. 8 | 310. 0 | | |
| 28 | 311. 1 | 312. 2 | 313. 3 | 314. 4 | 315. 5 | 316. 6 | 317. 7 | 318. 8 | 320. 0 | 321. 1 | | |
| 29 | 322. 2 | 323. 3 | 324. 4 | 325. 5 | 326. 6 | 327. 7 | 328. 8 | 330. 0 | 331. 1 | 332. 2 | | |
| 30 | 333. 3 | 334. 4 | 335. 5 | 336. 6 | 337. 7 | 338. 8 | 340. 0 | 341. 1 | 342. 2 | 343. 3 | | |
| 31 | 344. 4 | 345. 5 | 346. 6 | 347. 7 | 348. 8 | 350. 0 | 351. 1 | 352. 2 | 353. 3 | 354. 4 | | |
| 32 | 355. 5 | 356. 6 | 357. 7 | 358. 8 | 360. 0 | 361. 1 | 362. 2 | 363. 3 | 364. 4 | 365. 5 | | |
| 33 | 366. 6 | 367. 7 | 368. 8 | 370. 0 | 371. 1 | 372. 2 | 373. 3 | 374. 4 | 375. 5 | 376. 6 | | |
| 34 | 377. 7 | 378. 8 | 380. 0 | 381. 1 | 382. 2 | 383. 3 | 384. 4 | 385. 5 | 386. 6 | 387. 7 | | |
| 35 | 388. 8 | 390. 0 | 391. 1 | 392. 2 | 393. 3 | 394. 4 | 395. 5 | 396. 6 | 397. 7 | 398. 8 | | |
| MINUTES | 0 | 0, (2) | 0185 | 0370 | 0555 | 0740 | 0925 | 1111 | 1296 | 1481 | 1666 | |
| | 1 | 1851 | 2037 | 2222 | 2407 | 2592 | 2777 | 2962 | 3148 | 3333 | 3518 | |
| | 2 | 3703 | 3888 | 4074 | 4259 | 4444 | 4629 | 4814 | 5000 | 5185 | 5370 | |
| | 3 | 5555 | 5740 | 5925 | 6111 | 6296 | 6481 | 6666 | 6851 | 7037 | 7222 | |
| | 4 | 7407 | 7592 | 7777 | 7962 | 8148 | 8333 | 8518 | 8703 | 8888 | 9074 | |
| | 5 | 9259 | 9444 | 9629 | 9814 | 1 Gr. | 1 0185 | 1 0370 | 1 0555 | 1 0740 | 1 0925 | |
| SECONDS | 0 | 0. 0 | 00309 | 00617 | 00926 | 01235 | 01543 | 01852 | 02160 | 02469 | 02778 | |
| | 1 | 03086 | 03395 | 03704 | 04012 | 04321 | 04630 | 04938 | 05247 | 05556 | 05864 | |
| | 2 | 06173 | 06481 | 06790 | 07099 | 07407 | 07716 | 08025 | 08333 | 08642 | 08951 | |
| | 3 | 09259 | 09568 | 09877 | 10185 | 10494 | 10802 | 11111 | 11420 | 11728 | 12037 | |
| | 4 | 12346 | 12654 | 12963 | 13272 | 13580 | 13889 | 14198 | 14506 | 14815 | 15123 | |
| | 5 | 15432 | 15741 | 16049 | 16358 | 16667 | 16975 | 17284 | 17593 | 17901 | 18210 | |
| | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |

[1] The last digit is periodic. [2] The last three digits are periodic.

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TABLE I.—*For converting degrees, minutes, and seconds into grades.*

| Degrees. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | (1) | 1.1 | 2.2 | 3.3 | 4.4 | 5.5 | 6.6 | 7.7 | 8.8 | 10.0 |
| 1 | 11.1 | 12.2 | 13.3 | 14.4 | 15.5 | 16.6 | 17.7 | 18.8 | 20.0 | 21.1 |
| 2 | 22.2 | 23.3 | 24.4 | 25.5 | 26.6 | 27.7 | 28.8 | 30.0 | 31.1 | 32.2 |
| 3 | 33.3 | 34.4 | 35.5 | 36.6 | 37.7 | 38.8 | 40.0 | 41.1 | 42.2 | 43.3 |
| 4 | 44 4 | 45.5 | 46.6 | 47.7 | 48.8 | 50.0 | 51.1 | 52.2 | 53.3 | 54.4 |
| 5 | 55.5 | 56.6 | 57.7 | 58.8 | 60.0 | 61.1 | 62.2 | 63.3 | 64.4 | 65.5 |
| 6 | 66.6 | 67.7 | 68.8 | 70.0 | 71.1 | 72.2 | 73.3 | 74.4 | 75.5 | 76.6 |
| 7 | 77.7 | 78.8 | 80.0 | 81.1 | 82.2 | 83.3 | 84.4 | 85.5 | 86.6 | 87.7 |
| 8 | 88.8 | 90.0 | 91.1 | 92.2 | 93.3 | 94.4 | 95.5 | 96.6 | 97.7 | 98.8 |
| 9 | 100.0 | 101.1 | 102.2 | 103.3 | 104.4 | 105.5 | 106.6 | 107.7 | 108.8 | 110.0 |
| 10 | 111.1 | 112.2 | 113.3 | 114.4 | 115.5 | 116.6 | 117.7 | 118.8 | 120.0 | 121.1 |
| 11 | 122.2 | 123.3 | 124.4 | 125.5 | 126.6 | 127.7 | 128.8 | 130.0 | 131.1 | 132.2 |
| 12 | 133.3 | 134.4 | 135.5 | 136.6 | 137.7 | 138.8 | 140.0 | 141.1 | 142.2 | 143.3 |
| 13 | 144.4 | 145.5 | 146.6 | 147.7 | 148.8 | 150.0 | 151.1 | 152.2 | 153.3 | 154.4 |
| 14 | 155.5 | 156.6 | 157.7 | 158.8 | 160.0 | 161.1 | 162.2 | 163.3 | 164.4 | 165.5 |
| 15 | 166.6 | 167.7 | 168.8 | 170.0 | 171.1 | 172.2 | 173.3 | 174.4 | 175.5 | 176.6 |
| 16 | 177.7 | 178.8 | 180.0 | 181.1 | 182.2 | 183.3 | 184.4 | 185.5 | 186.6 | 187.7 |
| 17 | 188.8 | 190.0 | 191.1 | 192.2 | 193.3 | 194.4 | 195.5 | 196.6 | 197.7 | 198.8 |
| 18 | 200.0 | 201.1 | 202.2 | 203.3 | 204.4 | 205.5 | 206.6 | 207.7 | 208.8 | 210.0 |
| 19 | 211.1 | 212.2 | 213.3 | 214.4 | 215.5 | 216.6 | 217.7 | 218.8 | 220.0 | 221.1 |
| 20 | 222.2 | 223.3 | 224.4 | 225.5 | 226.6 | 227.7 | 228.8 | 230.0 | 231.1 | 232.2 |
| 21 | 233.3 | 234.4 | 235.5 | 236.6 | 237.7 | 238.8 | 240.0 | 241.1 | 242.2 | 243.3 |
| 22 | 244.4 | 245.5 | 246 6 | 247.7 | 248.8 | 250.0 | 251.1 | 252.2 | 253.3 | 254.4 |
| 23 | 255.5 | 256.6 | 257.7 | 258.8 | 260.0 | 261.1 | 262.2 | 263.3 | 264.4 | 265.5 |
| 24 | 266.6 | 267.7 | 268.8 | 270.0 | 271.1 | 272.2 | 273.3 | 274.4 | 275.5 | 276.6 |
| 25 | 277.7 | 278.8 | 280.0 | 281.1 | 282.2 | 283.3 | 284.4 | 285.5 | 286.6 | 287.7 |
| 26 | 288.8 | 290.0 | 291.1 | 292.2 | 293.3 | 294.4 | 295.5 | 296.6 | 297.7 | 298.8 |

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|---|---|---|---|---|---|---|---|---|---|---|---|
| 27 | | 300.0 | 301.1 | 302.2 | 303.3 | 304.4 | 305.5 | 306.6 | 307.7 | 308.8 | 310.0 |
| 28 | | 311.1 | 312.2 | 313.3 | 314.4 | 315.5 | 316.6 | 317.7 | 318.8 | 320.0 | 321.1 |
| 29 | | 322.2 | 323.3 | 324.4 | 325.5 | 326.6 | 327.7 | 328.8 | 330.0 | 331.1 | 332.2 |
| 30 | | 333.3 | 334.4 | 335.5 | 336.6 | 337.7 | 338.8 | 340.0 | 341.1 | 342.2 | 343.3 |
| 31 | | 344.4 | 345.5 | 346.6 | 347.7 | 348.8 | 350.0 | 351.1 | 352.2 | 353.3 | 354.4 |
| 32 | | 355.5 | 356.6 | 357.7 | 358.8 | 360.0 | 361.1 | 362.2 | 363.3 | 364.4 | 365.5 |
| 33 | | 366.6 | 367.7 | 368.8 | 370.0 | 371.1 | 372.2 | 373.3 | 374.4 | 375.5 | 376.6 |
| 34 | | 377.7 | 378.8 | 380.0 | 381.1 | 382.2 | 383.3 | 384.4 | 385.5 | 386.6 | 387.7 |
| 35 | | 388.8 | 390.0 | 391.1 | 392.2 | 393.3 | 394.4 | 395.5 | 396.6 | 397.7 | 398.8 |
| MINUTES | 0 | 0, (1) | 0185 | 0370 | 0555 | 0740 | 0925 | 1111 | 1296 | 1481 | 1666 |
| | 1 | 1851 | 2037 | 2222 | 2407 | 2592 | 2777 | 2962 | 3148 | 3333 | 3518 |
| | 2 | 3703 | 3888 | 4074 | 4259 | 4444 | 4629 | 4814 | 5000 | 5185 | 5370 |
| | 3 | 5555 | 5740 | 5925 | 6111 | 6296 | 6481 | 6666 | 6851 | 7037 | 7222 |
| | 4 | 7407 | 7592 | 7777 | 7962 | 8148 | 8333 | 8518 | 8703 | 8888 | 9074 |
| | 5 | 9259 | 9444 | 9629 | 9814 | 1 Gr. | 0185 | 1 0370 | 1 0555 | 1 0740 | 1 0925 |
| SECONDS | 0 | 0.0 | 00309 | 00617 | 00926 | 01235 | 01543 | 01852 | 02160 | 02469 | 02778 |
| | 1 | 03086 | 03395 | 03704 | 04012 | 04321 | 04630 | 04938 | 05247 | 05556 | 05864 |
| | 2 | 06173 | 06481 | 06790 | 07099 | 07407 | 07716 | 08025 | 08333 | 08642 | 08951 |
| | 3 | 09259 | 09568 | 09877 | 10185 | 10494 | 10802 | 11111 | 11420 | 11728 | 12037 |
| | 4 | 12346 | 12654 | 12963 | 13272 | 13580 | 13889 | 14198 | 14506 | 14815 | 15123 |
| | 5 | 15432 | 15741 | 16049 | 16358 | 16667 | 16975 | 17284 | 17593 | 17901 | 18210 |
| | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

[1] The last digit is periodic. [2] The last three digits are periodic.

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TABLE II.—*For converting grades into degrees and minutes.*

| Grades. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0′ | 54′ | 48′ | 42′ | 36′ | 30′ | 24′ | 18′ | 12′ | 6′ |
| 0 | 0° | 0° | 1° | 2° | 3° | 4° | 5° | 6° | 7° | 8° |
| 1 | 9 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| 2 | 18 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 |
| 3 | 27 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 |
| 4 | 36 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 |
| | 0′ | 54′ | 48′ | 42′ | 36′ | 30′ | 24′ | 18′ | 12′ | 6′ |
| 5 | 45° | 45° | 46° | 47° | 48° | 49° | 50° | 51° | 52° | 53° |
| 6 | 54 | 54 | 55 | 56 | 57 | 58 | 59 | 60 | 61 | 62 |
| 7 | 63 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 70 | 71 |
| 8 | 72 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 | 80 |
| 9 | 81 | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 |
| | 0′ | 54′ | 48′ | 42′ | 36′ | 30′ | 24′ | 18′ | 12′ | 6′ |
| 10 | 90° | 90° | 91° | 92° | 93° | 94° | 95° | 96° | 97° | 98° |
| 11 | 99 | 99 | 100 | 101 | 102 | 103 | 104 | 105 | 106 | 107 |
| 12 | 108 | 108 | 109 | 110 | 111 | 112 | 113 | 114 | 115 | 116 |
| 13 | 117 | 117 | 118 | 119 | 120 | 121 | 122 | 123 | 124 | 125 |
| 14 | 126 | 126 | 127 | 128 | 129 | 130 | 131 | 132 | 133 | 134 |
| | 0′ | 54′ | 48′ | 42′ | 36′ | 30′ | 24′ | 18′ | 12′ | 6′ |
| 15 | 135° | 135° | 136° | 137° | 138° | 139° | 140° | 141° | 142° | 143° |
| 16 | 144 | 144 | 145 | 146 | 147 | 148 | 149 | 150 | 151 | 152 |
| 17 | 153 | 153 | 154 | 155 | 156 | 157 | 158 | 159 | 160 | 161 |
| 18 | 162 | 162 | 163 | 164 | 165 | 166 | 167 | 168 | 169 | 170 |
| 19 | 171 | 171 | 172 | 173 | 174 | 175 | 176 | 177 | 178 | 179 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 | 180° | 0′ | 180° | 54′ | 181° | 48′ | 182° | 42′ | 183° | 36′ | 184° | 30′ | 185° | 24′ | 186° | 18′ | 187° | 12′ | 188° | 6′ |
| 21 | 189 | | 189 | | 190 | | 191 | | 192 | | 193 | | 194 | | 195 | | 196 | | 197 | |
| 22 | 198 | | 198 | | 199 | | 200 | | 201 | | 202 | | 203 | | 204 | | 205 | | 206 | |
| 23 | 207 | | 207 | | 208 | | 209 | | 210 | | 211 | | 212 | | 213 | | 214 | | 215 | |
| 24 | 216 | | 216 | | 217 | | 218 | | 219 | | 220 | | 221 | | 222 | | 223 | | 224 | |
| 25 | 225° | 0′ | 225° | 54′ | 226° | 48′ | 227° | 42′ | 228° | 36′ | 229° | 30′ | 230° | 24′ | 231° | 18′ | 232° | 12′ | 233° | 6′ |
| 26 | 234 | | 234 | | 235 | | 236 | | 237 | | 238 | | 239 | | 240 | | 241 | | 242 | |
| 27 | 243 | | 243 | | 244 | | 245 | | 246 | | 247 | | 248 | | 249 | | 250 | | 251 | |
| 28 | 252 | | 252 | | 253 | | 254 | | 255 | | 256 | | 257 | | 258 | | 259 | | 260 | |
| 29 | 261 | | 261 | | 262 | | 263 | | 264 | | 265 | | 266 | | 267 | | 268 | | 269 | |
| 30 | 270° | 0′ | 270° | 54′ | 271° | 48′ | 272° | 42′ | 273° | 36′ | 274° | 30′ | 275° | 24′ | 276° | 18′ | 277° | 12′ | 278° | 6′ |
| 31 | 279 | | 279 | | 280 | | 281 | | 282 | | 283 | | 284 | | 285 | | 286 | | 287 | |
| 32 | 288 | | 288 | | 289 | | 290 | | 291 | | 292 | | 293 | | 294 | | 295 | | 296 | |
| 33 | 297 | | 297 | | 298 | | 299 | | 300 | | 301 | | 302 | | 303 | | 304 | | 305 | |
| 34 | 306 | | 306 | | 307 | | 308 | | 309 | | 310 | | 311 | | 312 | | 313 | | 314 | |
| 35 | 315° | 0′ | 315° | 54′ | 316° | 48′ | 317° | 42′ | 318° | 36′ | 319° | 30′ | 320° | 24′ | 321° | 18′ | 322° | 12′ | 323° | 6′ |
| 36 | 324 | | 324 | | 325 | | 326 | | 327 | | 328 | | 329 | | 330 | | 331 | | 332 | |
| 37 | 333 | | 333 | | 334 | | 335 | | 336 | | 337 | | 338 | | 339 | | 340 | | 341 | |
| 38 | 342 | | 342 | | 343 | | 344 | | 345 | | 346 | | 347 | | 348 | | 349 | | 350 | |
| 39 | 351 | | 351 | | 352 | | 353 | | 354 | | 355 | | 356 | | 357 | | 358 | | 359 | |
| Grades. | 0 | | 1 | | 2 | | 3 | | 4 | | 5 | | 6 | | 7 | | 8 | | 9 | |

TABLE III.—*For converting centigrades (1/100 of a grade) into minutes and seconds.*

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0′ | 0 | 20′ | 10′48″.0 | 40′ | 21′36″.0 | 60′ | 32′24″.0 | 80′ | 43′12″.0 |
| 1 | 0′32″.4 | 21 | 11 20 .4 | 41 | 22 8 .4 | 61 | 32 56 .4 | 81 | 43 44 .4 |
| 2 | 1 4 .8 | 22 | 11 52 .8 | 2 | 22 40 .8 | 62 | 33 28 .8 | 82 | 44 16 .8 |
| 3 | 1 37 .2 | 23 | 12 25 .2 | 43 | 23 13 .2 | 63 | 34 1 .2 | 83 | 44 49 .2 |
| 4 | 2 9 .6 | 24 | 12 57 .6 | 44 | 23 45 .6 | 64 | 34 33 .6 | 84 | 45 21 .6 |
| 5′ | 2′42″.0 | 25′ | 13′30″.0 | 45′ | 24′18″.0 | 65′ | 35′ 6″.0 | 85′ | 45′54″.0 |
| 6 | 3 14 .4 | 26 | 14 2 .4 | 46 | 24 50 .4 | 66 | 35 38 .4 | 86 | 46 26 .4 |
| 7 | 3 46 .8 | 27 | 14 34 .8 | 47 | 25 22 .8 | 67 | 36 10 .8 | 87 | 46 58 .8 |
| 8 | 4 19 .2 | 28 | 15 7 .2 | 48 | 25 55 .2 | 68 | 36 43 .2 | 88 | 47 31 .2 |
| 9 | 4 51 .6 | 29 | 15 39 .6 | 49 | 26 27 .6 | 69 | 37 15 .6 | 89 | 48 3 .6 |
| 10′ | 5′24″.0 | 30′ | 16′12″.0 | 50′ | 27′ 0″.0 | 70′ | 37′48″.0 | 90′ | 48′36″.0 |
| 11 | 5 56 .4 | 31 | 16 44 .4 | 51 | 27 32 .4 | 71 | 38 20 .4 | 91 | 49 8 .4 |
| 12 | 6 28 .8 | 32 | 17 16 .8 | 52 | 28 4 .8 | 72 | 38 52 .8 | 92 | 49 40 .8 |
| 13 | 7 1 .2 | 33 | 17 49 .2 | 53 | 28 37 .2 | 73 | 39 25 .2 | 93 | 50 13 .2 |
| 14 | 7 33 .6 | 34 | 18 21 .6 | 54 | 29 9 .6 | 74 | 39 57 .6 | 94 | 50 45 .6 |
| 15′ | 8′ 6″.0 | 35′ | 18′54″.0 | 55′ | 29′42″.0 | 75′ | 40′30″.0 | 95′ | 51′18″.0 |
| 16 | 8 38 .4 | 36 | 19 26 .4 | 56 | 30 14 .4 | 76 | 41 2 .4 | 96 | 51 50 .4 |
| 17 | 9 10 .8 | 37 | 19 58 .8 | 57 | 30 46 .8 | 77 | 41 34 .8 | 97 | 52 22 .8 |
| 18 | 9 43 .2 | 38 | 20 31 .2 | 58 | 31 19 .2 | 78 | 42 7 .2 | 98 | 52 55 .2 |
| 19 | 10 15 .6 | 39 | 21 3 .6 | 59 | 31 51 .6 | 79 | 42 39 .6 | 99 | 53 27 .6 |

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TABLE IV.—*For converting decimilligrades (1/100 of a centigrade, or 1/10000 of a grade) into seconds.*

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0″ | 0″. | 20″ | 6″.48 | 40″ | 12″.96 | 60″ | 19″.44 | 80″ | 25″.92 |
| 1 | 0 .324 | 21 | 6 .804 | 41 | 13 .284 | 61 | 19 .764 | 81 | 26 .244 |
| 2 | 0 .648 | 22 | 7 .128 | 42 | 13 .608 | 62 | 20 .088 | 82 | 26 .568 |
| 3 | 0 .972 | 23 | 7 .452 | 43 | 13 .932 | 63 | 20 .412 | 83 | 26 .892 |
| 4 | 1 .296 | 24 | 7 .776 | 44 | 14 .256 | 64 | 20 .736 | 84 | 27 .216 |
| 5″ | 1″.62 | 25″ | 8″.1 | 45″ | 14″.58 | 65″ | 21″.06 | 85″ | 27″.54 |
| 6 | 1 .944 | 26 | 8 .424 | 46 | 14 .904 | 66 | 21 .384 | 86 | 27 .864 |
| 7 | 2 .268 | 27 | 8 .748 | 47 | 15 .228 | 67 | 21 .708 | 87 | 28 .188 |
| 8 | 2 .592 | 28 | 9 .072 | 48 | 15 .552 | 68 | 22 .032 | 88 | 28 .512 |
| 9 | 2 .916 | 29 | 9 .396 | 49 | 15 .876 | 69 | 22 .356 | 89 | 28 .836 |
| 10″ | 3″.24 | 30″ | 9″.72 | 50″ | 16″.2 | 70″ | 22″.68 | 90″ | 29″.16 |
| 11 | 3 .564 | 31 | 10 .044 | 51 | 16 .524 | 71 | 23 .004 | 91 | 29 .484 |
| 12 | 3 .888 | 32 | 10 .368 | 52 | 16 .848 | 72 | 23 .328 | 92 | 29 .808 |
| 13 | 4 .212 | 33 | 10 .692 | 53 | 17 .172 | 73 | 23 .652 | 93 | 30 .132 |
| 14 | 4 .536 | 34 | 11 .016 | 54 | 17 .496 | 74 | 23 .976 | 94 | 30 .456 |
| 15″ | 4″.86 | 35″ | 11″.34 | 55″ | 17″.82 | 75″ | 24″.3 | 95″ | 30″.78 |
| 16 | 5 .184 | 36 | 11 .664 | 56 | 18 .144 | 76 | 24 .624 | 96 | 31 .104 |
| 17 | 5 .508 | 37 | 11 .988 | 57 | 18 .468 | 77 | 24 .948 | 97 | 31 .428 |
| 18 | 5 .832 | 38 | 12 .312 | 58 | 18 .792 | 78 | 26 .272 | 98 | 31 .752 |
| 19 | 6 .156 | 39 | 12 .636 | 59 | 19 .116 | 79 | 25 .596 | 99 | 32 .076 |

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TABLE V.—*For converting minutes and seconds into thousandths of a degree.*

| Minimum | 0 | 3 | 6 | 9 | 12 | 15 | 18 | 21 | 24 | 27 | 30 | 33 | 36 | 39 | 42 | 45 | 48 | 51 | 54 | 57 | Sec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 51 | 101 | 151 | 201 | 251 | 301 | 351 | 401 | 451 | 501 | 551 | 601 | 651 | 701 | 751 | 801 | 851 | 901 | 951 | 3. 6 |
| | 2 | 52 | 102 | 152 | 202 | 252 | 302 | 352 | 402 | 452 | 502 | 552 | 602 | 652 | 702 | 752 | 802 | 852 | 902 | 952 | 7. 2 |
| | 3 | 53 | 103 | 153 | 203 | 253 | 303 | 353 | 403 | 453 | 503 | 553 | 603 | 653 | 703 | 753 | 803 | 853 | 903 | 953 | 10. 8 |
| | 4 | 54 | 104 | 154 | 204 | 254 | 304 | 354 | 404 | 454 | 504 | 554 | 604 | 654 | 704 | 754 | 804 | 854 | 904 | 954 | 14. 4 |
| | 5 | 55 | 105 | 155 | 205 | 255 | 305 | 355 | 405 | 455 | 505 | 555 | 605 | 655 | 705 | 755 | 805 | 855 | 905 | 955 | 18. 0 |
| | 6 | 56 | 106 | 156 | 206 | 256 | 306 | 356 | 406 | 456 | 506 | 556 | 606 | 656 | 706 | 756 | 806 | 856 | 906 | 956 | 21. 6 |
| | 7 | 57 | 107 | 157 | 207 | 257 | 307 | 357 | 407 | 457 | 507 | 557 | 607 | 657 | 707 | 757 | 807 | 857 | 907 | 957 | 25. 2 |
| | 8 | 58 | 108 | 158 | 208 | 258 | 308 | 358 | 408 | 458 | 508 | 558 | 608 | 658 | 708 | 758 | 808 | 858 | 908 | 958 | 28. 8 |
| | 9 | 59 | 109 | 159 | 209 | 259 | 309 | 359 | 409 | 459 | 509 | 559 | 609 | 659 | 709 | 759 | 809 | 859 | 909 | 959 | 32. 4 |
| | 10 | 60 | 110 | 160 | 210 | 260 | 310 | 360 | 410 | 460 | 510 | 560 | 610 | 660 | 710 | 760 | 810 | 860 | 910 | 960 | 36. 0 |
| | 11 | 61 | 111 | 161 | 211 | 261 | 311 | 361 | 411 | 461 | 511 | 561 | 611 | 661 | 711 | 761 | 811 | 861 | 911 | 961 | 39. 6 |
| | 12 | 62 | 112 | 162 | 212 | 262 | 312 | 362 | 412 | 462 | 512 | 562 | 612 | 662 | 712 | 762 | 812 | 862 | 912 | 962 | 43. 2 |
| | 13 | 63 | 113 | 163 | 213 | 263 | 313 | 363 | 413 | 463 | 513 | 563 | 613 | 663 | 713 | 763 | 813 | 863 | 913 | 963 | 46. 8 |
| | 14 | 64 | 114 | 164 | 214 | 264 | 314 | 364 | 414 | 464 | 514 | 564 | 614 | 664 | 714 | 764 | 814 | 864 | 914 | 964 | 50. 4 |
| | 15 | 65 | 115 | 165 | 215 | 265 | 315 | 365 | 415 | 465 | 515 | 565 | 615 | 665 | 715 | 765 | 815 | 865 | 915 | 965 | 54. 0 |
| | 16 | 66 | 116 | 166 | 216 | 266 | 316 | 366 | 416 | 466 | 516 | 566 | 616 | 666 | 716 | 766 | 816 | 866 | 916 | 966 | 57. 6 |
| Minimum | 1 | 4 | 7 | 10 | 13 | 16 | 19 | 22 | 25 | 28 | 31 | 34 | 37 | 40 | 43 | 64 | 49 | 52 | 55 | 58 | |
| | 17 | 67 | 117 | 167 | 217 | 267 | 317 | 367 | 417 | 467 | 517 | 567 | 617 | 667 | 717 | 767 | 817 | 867 | 917 | 967 | 1. 2 |
| | 18 | 68 | 118 | 168 | 218 | 268 | 318 | 368 | 418 | 468 | 518 | 568 | 618 | 668 | 718 | 768 | 818 | 868 | 918 | 968 | 4. 8 |
| | 19 | 69 | 119 | 169 | 219 | 269 | 319 | 369 | 419 | 469 | 519 | 569 | 619 | 669 | 719 | 769 | 819 | 869 | 919 | 969 | 8. 4 |
| | 20 | 70 | 120 | 170 | 220 | 270 | 320 | 370 | 420 | 470 | 520 | 570 | 620 | 670 | 720 | 770 | 820 | 870 | 920 | 970 | 12. 0 |
| | 21 | 71 | 121 | 171 | 221 | 271 | 321 | 371 | 421 | 471 | 521 | 571 | 621 | 671 | 721 | 771 | 821 | 871 | 921 | 971 | 15. 6 |
| | 22 | 72 | 122 | 172 | 222 | 272 | 322 | 372 | 422 | 472 | 522 | 572 | 622 | 672 | 722 | 772 | 822 | 872 | 922 | 972 | 19. 2 |
| | 23 | 73 | 123 | 173 | 223 | 273 | 323 | 373 | 423 | 473 | 523 | 573 | 623 | 673 | 723 | 773 | 823 | 873 | 923 | 973 | 22. 8 |

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| Minimum | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 5 | 8 | 11 | 14 | 17 | 20 | 23 | 26 | 29 | 32 | 35 | 38 | 41 | 44 | 47 | 50 | 53 | 56 | 59 | | | | | | | | | | | | | |
| 24 | 74 | 124 | 174 | 224 | 274 | 324 | 374 | 424 | 474 | 524 | 574 | 624 | 674 | 724 | 774 | 824 | 874 | 924 | 974 | 26.4 | | | | | | | | | | | | |
| 25 | 75 | 125 | 175 | 225 | 275 | 325 | 375 | 425 | 475 | 525 | 575 | 625 | 675 | 725 | 775 | 825 | 875 | 925 | 975 | 30.0 | | | | | | | | | | | | |
| 26 | 76 | 126 | 176 | 226 | 276 | 326 | 376 | 426 | 476 | 526 | 576 | 626 | 676 | 726 | 776 | 826 | 876 | 926 | 976 | 33.6 | | | | | | | | | | | | |
| 27 | 77 | 127 | 177 | 227 | 277 | 327 | 377 | 427 | 477 | 527 | 577 | 627 | 677 | 727 | 777 | 827 | 877 | 927 | 977 | 37.2 | | | | | | | | | | | | |
| 28 | 78 | 128 | 178 | 228 | 278 | 328 | 378 | 428 | 478 | 528 | 578 | 628 | 678 | 728 | 778 | 828 | 878 | 928 | 978 | 40.8 | | | | | | | | | | | | |
| 29 | 79 | 129 | 179 | 229 | 279 | 329 | 379 | 429 | 479 | 529 | 579 | 629 | 679 | 729 | 779 | 829 | 879 | 929 | 979 | 44.4 | | | | | | | | | | | | |
| 30 | 80 | 130 | 180 | 230 | 280 | 330 | 380 | 430 | 480 | 530 | 580 | 630 | 680 | 730 | 780 | 830 | 880 | 930 | 980 | 48.0 | | | | | | | | | | | | |
| 31 | 81 | 131 | 181 | 231 | 281 | 331 | 381 | 431 | 481 | 531 | 581 | 631 | 681 | 731 | 781 | 831 | 881 | 931 | 981 | 51.6 | | | | | | | | | | | | |
| 32 | 82 | 132 | 182 | 232 | 282 | 332 | 382 | 432 | 482 | 532 | 582 | 632 | 682 | 732 | 782 | 832 | 882 | 932 | 982 | 55.2 | | | | | | | | | | | | |
| 33 | 83 | 133 | 183 | 233 | 283 | 333 | 383 | 433 | 483 | 533 | 583 | 633 | 683 | 733 | 783 | 833 | 883 | 933 | 983 | 58.8 | | | | | | | | | | | | |
| 34 | 84 | 134 | 184 | 234 | 284 | 334 | 384 | 434 | 484 | 534 | 584 | 634 | 684 | 734 | 784 | 834 | 884 | 934 | 984 | 2.4 | | | | | | | | | | | | |
| 35 | 85 | 135 | 185 | 235 | 285 | 335 | 385 | 435 | 485 | 535 | 585 | 635 | 685 | 735 | 785 | 835 | 885 | 935 | 985 | 6.0 | | | | | | | | | | | | |
| 36 | 86 | 136 | 186 | 236 | 286 | 336 | 386 | 436 | 486 | 536 | 586 | 636 | 686 | 736 | 786 | 836 | 886 | 936 | 986 | 9.6 | | | | | | | | | | | | |
| 37 | 87 | 137 | 187 | 237 | 287 | 337 | 387 | 437 | 487 | 537 | 587 | 637 | 687 | 737 | 787 | 837 | 887 | 937 | 987 | 13.2 | | | | | | | | | | | | |
| 38 | 88 | 138 | 188 | 238 | 288 | 338 | 388 | 438 | 488 | 538 | 588 | 638 | 688 | 738 | 788 | 838 | 888 | 938 | 988 | 16.8 | | | | | | | | | | | | |
| 39 | 89 | 139 | 189 | 239 | 289 | 339 | 389 | 439 | 489 | 539 | 589 | 639 | 689 | 739 | 789 | 839 | 889 | 939 | 989 | 20.4 | | | | | | | | | | | | |
| 40 | 90 | 140 | 190 | 240 | 290 | 340 | 390 | 440 | 490 | 540 | 590 | 640 | 690 | 740 | 790 | 840 | 890 | 940 | 990 | 24.0 | | | | | | | | | | | | |
| 41 | 91 | 141 | 191 | 241 | 291 | 341 | 391 | 441 | 491 | 541 | 591 | 641 | 691 | 741 | 791 | 841 | 891 | 941 | 991 | 27.6 | | | | | | | | | | | | |
| 42 | 92 | 142 | 192 | 242 | 292 | 342 | 392 | 442 | 492 | 542 | 592 | 642 | 692 | 742 | 792 | 842 | 892 | 942 | 992 | 31.2 | | | | | | | | | | | | |
| 43 | 93 | 143 | 193 | 243 | 293 | 343 | 393 | 443 | 493 | 543 | 593 | 643 | 693 | 743 | 793 | 843 | 893 | 943 | 993 | 34.8 | | | | | | | | | | | | |
| 44 | 94 | 144 | 194 | 244 | 294 | 344 | 394 | 444 | 494 | 544 | 594 | 644 | 694 | 744 | 794 | 844 | 894 | 944 | 994 | 38.4 | | | | | | | | | | | | |
| 45 | 95 | 145 | 195 | 245 | 295 | 345 | 395 | 445 | 495 | 545 | 595 | 645 | 695 | 745 | 795 | 845 | 895 | 945 | 995 | 42.0 | | | | | | | | | | | | |
| 46 | 96 | 146 | 196 | 246 | 296 | 346 | 396 | 446 | 496 | 546 | 596 | 646 | 696 | 746 | 796 | 846 | 896 | 946 | 996 | 45.6 | | | | | | | | | | | | |
| 47 | 97 | 147 | 197 | 247 | 297 | 347 | 397 | 447 | 497 | 547 | 597 | 647 | 697 | 747 | 797 | 847 | 897 | 947 | 997 | 49.2 | | | | | | | | | | | | |
| 48 | 98 | 148 | 198 | 248 | 298 | 348 | 398 | 448 | 498 | 548 | 598 | 648 | 698 | 748 | 798 | 848 | 898 | 948 | 998 | 52.8 | | | | | | | | | | | | |
| 49 | 99 | 149 | 199 | 249 | 299 | 349 | 399 | 449 | 499 | 549 | 599 | 649 | 699 | 749 | 799 | 849 | 899 | 949 | 999 | 56.4 | | | | | | | | | | | | |
| 50 | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 | 550 | 600 | 650 | 700 | 750 | 800 | 850 | 900 | 950 | 1000 | 60.0 | | | | | | | | | | | | |

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TABLE VI.—*For converting degrees into mils (6400).*

| Degrees. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Degrees. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | ..... | 18 | 36 | 53 | 71 | 89 | 107 | 124 | 142 | 160 | 0 |
| 1 | 178 | 196 | 213 | 231 | 249 | 267 | 284 | 302 | 320 | 338 | 1 |
| 2 | 356 | 373 | 391 | 409 | 427 | 444 | 462 | 480 | 498 | 516 | 2 |
| 3 | 533 | 551 | 569 | 587 | 604 | 622 | 640 | 658 | 676 | 693 | 3 |
| 4 | 711 | 729 | 747 | 764 | 782 | 800 | 818 | 836 | 853 | 871 | 4 |
| 5 | 889 | 907 | 924 | 942 | 960 | 978 | 996 | 1,013 | 1,031 | 1,049 | 5 |
| 6 | 1,067 | 1,084 | 1,102 | 1,120 | 1,138 | 1,156 | 1,173 | 1,191 | 1,209 | 1,227 | 6 |
| 7 | 1,244 | 1,262 | 1,280 | 1,298 | 1,315 | 1,333 | 1,351 | 1,369 | 1,387 | 1,404 | 7 |
| 8 | 1,422 | 1,440 | 1,458 | 1,475 | 1,493 | 1,511 | 1,529 | 1,547 | 1,564 | 1,582 | 8 |
| 9 | 1,600 | 1,618 | 1,636 | 1,653 | 1,671 | 1,689 | 1,707 | 1,724 | 1,742 | 1,760 | 9 |
| 10 | 1,778 | 1,796 | 1,813 | 1,831 | 1,849 | 1,867 | 1,884 | 1,902 | 1,920 | 1,938 | 10 |
| 11 | 1,956 | 1,973 | 1,991 | 2,009 | 2,027 | 2,044 | 2,062 | 2,080 | 2,098 | 2,116 | 11 |
| 12 | 2,133 | 2,151 | 2,169 | 2,187 | 2,204 | 2,222 | 2,240 | 2,258 | 2,276 | 2,293 | 12 |
| 13 | 2,311 | 2,329 | 2,347 | 2,364 | 2,382 | 2,400 | 2,418 | 2,436 | 2,453 | 2,471 | 13 |
| 14 | 2,489 | 2,507 | 2,524 | 2,542 | 2,560 | 2,578 | 2,596 | 2,613 | 2,631 | 2,649 | 14 |
| 15 | 2,667 | 2,684 | 2,702 | 2,720 | 2,738 | 2,756 | 2,773 | 2,791 | 2,809 | 2,827 | 15 |
| 16 | 2,844 | 2,862 | 2,880 | 2,898 | 2,915 | 2,933 | 2,951 | 2,969 | 2,987 | 3,004 | 16 |
| 17 | 3,022 | 3,040 | 3,058 | 3,075 | 3,093 | 3,111 | 3,129 | 3,147 | 3,164 | 3,182 | 17 |
| 18 | 3,200 | 3,218 | 3,236 | 3,253 | 3,271 | 3,289 | 3,307 | 3,324 | 3,342 | 3,360 | 18 |
| 19 | 3,378 | 3,396 | 3,413 | 3,431 | 3,449 | 3,467 | 3,484 | 3,502 | 3,520 | 3,538 | 19 |
| 20 | 3,556 | 3,573 | 3,591 | 3,609 | 3,627 | 3,644 | 3,662 | 3,680 | 3,698 | 3,716 | 20 |
| 21 | 3,733 | 3,751 | 3,769 | 3,787 | 3,804 | 3,822 | 3,840 | 3,858 | 3,876 | 3,893 | 21 |
| 22 | 3,911 | 3,929 | 3,947 | 3,964 | 3,982 | 4,000 | 4,018 | 4,036 | 4,053 | 4,071 | 22 |
| 23 | 4,089 | 4,107 | 4,124 | 4,142 | 4,160 | 4,178 | 4,196 | 4,213 | 4,231 | 4,249 | 23 |
| 24 | 4,267 | 4,284 | 4,302 | 4,320 | 4,338 | 4,356 | 4,373 | 4,391 | 4,409 | 4,427 | 24 |
| 25 | 4,444 | 4,462 | 4,480 | 4,498 | 4,515 | 4,533 | 4,551 | 4,569 | 4,587 | 4,604 | 25 |
| 26 | 4,622 | 4,640 | 4,658 | 4,675 | 4,693 | 4,711 | 4,729 | 4,747 | 4,764 | 4,782 | 26 |
| 27 | 4,800 | 4,818 | 4,836 | 4,853 | 4,871 | 4,889 | 4,907 | 4,924 | 4,942 | 4,960 | 27 |
| 28 | 4,978 | 4,996 | 5,013 | 5,031 | 5,049 | 5,067 | 5,084 | 5,102 | 5,120 | 5,138 | 28 |
| 29 | 5,156 | 5,173 | 5,191 | 5,209 | 5,227 | 5,244 | 5,262 | 5,280 | 5,298 | 5,316 | 29 |
| 30 | 5,333 | 5,351 | 5,369 | 5,387 | 5,404 | 5,422 | 5,440 | 5,458 | 5,476 | 5,493 | 30 |

| Mils. | Minimum. |
|---|---|
| 1 | 3 |
| 2 | 7 |
| 3 | 10 |
| 4 | 14 |
| 5 | 17 |
| 6 | 20 |
| 7 | 24 |
| 8 | 27 |
| 9 | 30 |
| 10 | 34 |
| 11 | 37 |
| 12 | 41 |
| 13 | 44 |
| 14 | 47 |
| 15 | 51 |
| 16 | 54 |
| 17 | 57 |

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| 31 | 5,511 | 5,529 | 5,547 | 5,564 | 5,582 | 5,600 | 5,618 | 5,636 | 5,653 | 5,671 | 31 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 32 | 5,689 | 5,707 | 5,724 | 5,742 | 5,760 | 5,778 | 5,796 | 5,813 | 5,831 | 5,849 | 32 |
| 33 | 5,867 | 5,884 | 5,902 | 5,920 | 5,938 | 5,956 | 5,973 | 5,991 | 6,009 | 6,027 | 33 |
| 34 | 6,044 | 6,062 | 6,080 | 6,098 | 6,115 | 6,133 | 6,151 | 6,169 | 6,187 | 6,204 | 34 |
| 35 | 6,222 | 6,240 | 6,258 | 6,275 | 6,293 | 6,311 | 6,329 | 6,347 | 6,364 | 6,382 | 35 |

| Min. | | | | | | | | | | | Min. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 0 |
| 1 | 3 | 3 | 4 | 4 | 4 | 4 | 5 | 5 | 5 | 6 | 1 |
| 2 | 6 | 6 | 7 | 7 | 7 | 7 | 8 | 8 | 8 | 9 | 2 |
| 3 | 9 | 9 | 9 | 10 | 10 | 10 | 11 | 11 | 11 | 12 | 3 |
| 4 | 12 | 12 | 13 | 13 | 13 | 14 | 14 | 14 | 14 | 15 | 4 |
| 5 | 15 | 15 | 16 | 16 | 16 | 16 | 17 | 17 | 17 | 17 | 5 |
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |

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TABLE VII.—*For converting grades into mils.*

| Grades. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Grades. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | 16 | 32 | 48 | 64 | 80 | 96 | 112 | 128 | 144 | 0 |
| 1 | 160 | 176 | 192 | 208 | 224 | 240 | 256 | 272 | 288 | 304 | 1 |
| 2 | 320 | 336 | 352 | 368 | 384 | 400 | 416 | 432 | 448 | 464 | 2 |
| 3 | 480 | 496 | 512 | 528 | 544 | 560 | 576 | 592 | 608 | 624 | 3 |
| 4 | 640 | 656 | 672 | 688 | 704 | 720 | 736 | 752 | 768 | 784 | 4 |
| 5 | 800 | 816 | 832 | 848 | 864 | 880 | 896 | 912 | 928 | 944 | 5 |
| 6 | 960 | 976 | 992 | 1,008 | 1,024 | 1,040 | 1,056 | 1,072 | 1,088 | 1,104 | 6 |
| 7 | 1,120 | 1,136 | 1,152 | 1,168 | 1,184 | 1,200 | 1,216 | 1,232 | 1,248 | 1,264 | 7 |
| 8 | 1,280 | 1,296 | 1,312 | 1,328 | 1,344 | 1,360 | 1,376 | 1,392 | 1,408 | 1,424 | 8 |
| 9 | 1,440 | 1,456 | 1,472 | 1,488 | 1,504 | 1,520 | 1,536 | 1,552 | 1,568 | 1,584 | 9 |
| Grades. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |

| Mils. | Grades. |
|---|---|
| 1 | 0.06 |
| 2 | .12 |
| 3 | .19 |
| 4 | .25 |
| 5 | .31 |
| 6 | .38 |
| 7 | .44 |
| 8 | .50 |
| 9 | .56 |
| 10 | .62 |
| 11 | .69 |
| 12 | .75 |
| 13 | .81 |
| 14 | .88 |
| 15 | .94 |
| 16 | 1.00 |

(Log. reduction factor 1.2041200.)

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# TABLES OF METRIC EQUIVALENTS.

## TABLE I.

### Linear equivalents.

| Mm. | Cm. | M. | Kilom. | In. | Ft. | Yds. | Mile. |
|---|---|---|---|---|---|---|---|
| 1 | 0.1 | 0.001 | ..... | 0.0394 | 0.0033 | 0.0011 | ..... |
| 10 | 1. | .01 | ..... | .3937 | .0328 | .0109 | ..... |
| 1000 | 100 | 1. | .001 | 39.37 | 3.281 | 1.0936 | .0006 |
| ..... | ..... | 1000 | 1. | 39370 | 3281 | 1093.6 | .6214 |
| 25.4 | 2.54 | .0254 | ..... | 1 | .083 | .0278 | ..... |
| 304.8 | 30.48 | .3048 | ..... | 12 | 1 | .333 | .00016 |
| ..... | 91.44 | .9144 | .00091 | 36 | 3 | 1 | .00057 |
| ..... | ..... | 1609 | 1.609 | 63360 | 5280 | 1760 | 1 |

## TABLE II.

### Volume and capacity equivalents.

| Cu. in. | Cu. ft. | Cu. yds. | U. S. quarts. | U. S. gallons. | Liters. |
|---|---|---|---|---|---|
| 1 | 0.00058 | 0.00002 | 0.01732 | 0.00433 | 0.01639 |
| 1728 | 1 | .03704 | 29.92 | 7.481 | 28.32 |
| 46656 | 27 | 1 | 807.9 | 202. | 764.6 |
| 57.75 | .03342 | .00124 | 1 | .25 | .9464 |
| 231 | .1337 | .00495 | 4 | 1 | 3.785 |
| 61.02 | .03531 | .00131 | 1.075 | .2642 | 1 |

## TABLE III.

### Area equivalents.

| Hectare. | Square meters. | Square inches. | Square feet. | Square yards. | Acres. | Square miles. |
|---|---|---|---|---|---|---|
| | 1 | 1550 | 10.76 | 1.196 | 0.00025 | ..... |
| | .00065 | 1 | .00694 | .0008 | ..... | ..... |
| | .09290 | 144 | 1 | .1111 | .00002 | ..... |
| | .8361 | 1296 | 9 | 1 | .00021 | ..... |
| | .4045 | ..... | 43560 | 4840 | 1 | 0.00156 |
| | 2589998 | ..... | ..... | 3097600 | 640 | 1 |
| 1 | 10000 | ..... | 107649 | 11961 | 247 | ..... |



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Take units of grades from top line, tens of grades from side column.

Examples: $88^{G}69 = 1408$ mils (from main table).
11 mils (from small table).

1419 mils.

1094 mils $= 68^{G}$ (see 1088 in main table).
.38 (see 6 in small table).

68.38 grades.

$247^{G}46 = 3840$ (use $24 \times 10 = 240$).
112 (7 grades).
7 (in small table, use .44 as nearest mil, all that is desired).

3959 mils.

4793 mils $= 300$ (4800 mils = 300 grades).
.44 ( 7 mils = .44).

299.56

**TABLE IV.**

**Weight equivalents.**

| Kg. | Oz. | Lbs. | Short tons. | Long tons. | Metric tons. |
|---|---|---|---|---|---|
| 1 | 35.27 | 2.204 | 0.0011 | 0.0009 | 0.001 |
| .02835 | 1 | .0625 | | | |
| .4536 | 16 | 1 | .0005 | .00044 | .00045 |
| 907.2 | 32,000 | 2,000 | 1 | .8929 | .9072 |
| 1,016 | 35,840 | 2,240 | 1.12 | 1 | 1.016 |
| 1,000 | 35,270 | 2,204 | 1.102 | .9842 | 1 |

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## TABLE V.

### Approximate metric equivalents.

*Length equivalents.*

| | | | |
|---|---|---|---|
| 1 millimeter | = | 0.04 inch. | |
| 1 centimeter | = | .4 inch. | |
| 1 decimeter | = | 4 inches. | |
| 1 meter | = | 10 decimeters | = 3 ft. 3 in. (39.37 in.). |
| 1 decameter | = | 10 meters | = 11 yards. |
| 1 hectometer | = | 100 meters | = 110 yards. |
| 1 kilometer | = | 1,000 meters | = $\frac{5}{8}$ mile. |
| 1 inch | = | 25 millimeters | = $2\frac{1}{2}$ centimeters. |
| 1 foot | = | 300 millimeters | = 30 centimeters. |
| 1 yard | = | 90 centimeters | = 9 decimeters. |
| 1 mile | = | 1,600 meters | = 1.6 kilometers. |

To obtain length in inches, multiply length in millimeters by 4 and point off 2 decimal places, viz.: 420 mm.$\times$4=16.80 inches. If distance is given in centimeters, proceed as above, pointing off only 1 decimal place.

To obtain length in centimeters or millimeters, divide length in inches by 4, pointing off 1 and 2 decimal places, respectively.

To convert kilometers to miles, multiply by 6 and point off 1 decimal place (i. e., multiply by 0.6), viz.: 11 km.=6.6 miles.

To convert miles to kilometers, divide by 6 and add one cipher, viz.: 72 miles=120 km. Or multiply distance in miles by 1.6, viz.: 10 miles=16 km.

*Weight equivalents.*

| | | |
|---|---|---|
| 500 grams | = | 1.1 lbs. |
| 1 kilogram | = | 1,000 grams=2.2 lbs. |
| 1 metric ton | = | 1,000 kg. =2,204 lbs. |

*Volume equivalents.*

| | | |
|---|---|---|
| 1 liter | = | 1,000 cubic centimeters=$\frac{9}{10}$ quart. |
| 1 gallon | = | 4 quarts =4.4 liters. |

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## APPENDIX 2.

## APPLICATION OF THE LAWS OF DISPERSION IN DEDUCING METHODS OF FIRE.

**388.** The methods of fire are based on the laws of dispersion, which are discussed in paragraphs 17 to 28.

**389. Trial fire.**—The object of trial fire is to place the zone of dispersion of a single elevation so as to include the objective (par. 203). The method consists in bracketing the objective between two **verified** elevations differing by four field probable errors (par. 215). The objective should then be within the zone of dispersion of the mid-elevation of the bracket.

**390.** Assume the range as about 5,000 meters, and the range probable error as 25 meters.

Trial fire gives a bracket of say 5,000–5,100.

The zone of dispersion of 5,000 is from 4,900 to 5,100. It is only known that 4,900 is short and 5,200 over. The objective is then between 4,900 and 5,200, almost certainly.

**391. Improvement fire.**—The prescribed method is to fire at the trial elevation (pars. 215 and 219), that is, at 5,050.

The zone of dispersion for 5,050 is between 4,950 and 5,150. Improvement fire is conditional on the zone of dispersion of the trial elevation covering the objective. If this is not the case, the adjustment must be begun anew (par. 222), as for example, if the objective be between 4,900 and 4,950, as A, or between 5,150 and 5,200, as B.

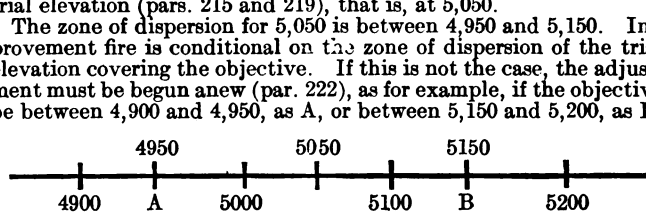


FIG. 51.

What is the probability of this occurring?

In firing at 5,000, the probability of a shot being short of 4,950 is 9 per cent (fig. 51). The probability of having two shots at 5,000 short of 4,950 is $.09 \times .09 = .0081$ (par. 26), which is applicable in this case, since the bracket was verified.



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It is thus seen that the probability of the objective being without the zone of dispersion of the trial elevation, after having obtained a verified bracket of one fork, is very slight. It is provided for in paragraph 222.

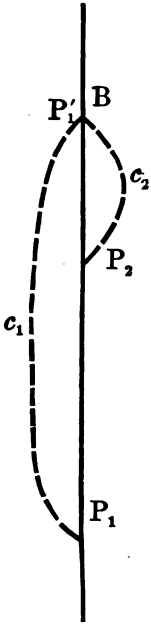

FIG. 52.

If the objective is two probable errors short of the range center (page 34, fig. 10), improvement fire of 12 rounds should, on the average, give 1 short and 11 overs. Paragraph 219 prescribes a change of elevation of five-twelfths of a fork in this case, or about one-half a fork. This would place the range center at the objective.

If the objective is one probable error beyond the range center, improvement fire of 12 rounds should, on the average, give 3 over and 9 short. The prescribed elevation change would then be three-twelfths of a fork, which would place the range center at the objective.

**392. Adjusted elevation.**—The adjusted elevation is only approximate. It is based on the application of the laws of dispersion to a limited number of events, whereas these laws are strictly correct only for an unlimited number of events.

The adjusted elevation must therefore be accepted only provisionally and be modified if necessary as a result of fire for effect (par. 254).

When fire for effect can not be observed, improvement fire must be continued.

**393. Precision fire for effect.**—Paragraph 254 prescribes series of 24 or 48 rounds. After each series a correction is made to reestablish an equality of shorts and overs. This correction is independent of series previously observed.

This is not correct mathematically. It has been adopted because it is simple, and tends to correct for variations of a systematic nature (temperature, barometer, heating of the pieces, etc.).

**394. Adjustment by means of the measured deviations of the shots** (par. 228).—Let B be the objective (fig. 52). $P_1$ the first shot of the adjustment or second of the fire fired with the elevation $H_1$, whose measured deviation is $c_1$.

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The elevation is changed by $c_1$, and the next shot $P_2$ fired at

$$H_2 = H_1 + c_1.$$

The deviation $c_2$ is measured.

It is reasonable to suppose that the shot $P'_1$, if fired with the elevation $H_2$, would have given a target shot.

The mean deviation of two shots, $P_2$ (actual) and $P'_1$ (fictitious) is then

$$\frac{0+c_2}{2} = \frac{c_2}{2}.$$

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# APPENDIX 3.

## CORRECTION FOR THE INCLINATION OF THE TRUNNIONS.

| ELEVATION. | INCLINATION OF THE TRUNNIONS (IN MILS). | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0° 10′ | 0° 20′ | 0° 30′ | 0° 40′ | 0° 50′ | 1° 00′ | 1° 10′ | 1° 20′ | 1° 30′ | 1° 40′ | 1° 50′ | 2° 00′ |
| 18° | 1.0 | 1.9 | 2.8 | 3.8 | 4.8 | 5.7 | 6.7 | 7.7 | 8.6 | 9.6 | 10.6 | 11.5 |
| 19° | 1.1 | 2.1 | 3.0 | 4.2 | 5.1 | 6.1 | 7.2 | 8.2 | 9.1 | 10.2 | 11.2 | 12.3 |
| 20° | 1.1 | 2.1 | 3.2 | 4.3 | 5.4 | 6.4 | 7.5 | 8.6 | 9.6 | 10.7 | 11.8 | 13.0 |
| 21° | 1.1 | 2.2 | 3.4 | 4.6 | 5.6 | 6.9 | 8.0 | 9.1 | 10.2 | 11.4 | 12.4 | 13.6 |
| 22° | 1.1 | 2.4 | 3.5 | 4.8 | 5.9 | 7.2 | 8.4 | 9.6 | 10.7 | 12.0 | 13.1 | 14.4 |
| 23° | 1.3 | 2.6 | 3.9 | 5.1 | 6.2 | 7.5 | 8.8 | 10.1 | 11.3 | 12.6 | 13.8 | 15.2 |
| 24° | 1.3 | 2.6 | 3.9 | 5.3 | 6.6 | 8.0 | 9.3 | 10.6 | 11.8 | 13.3 | 14.4 | 15.8 |
| 25° | 1.3 | 2.7 | 4.0 | 5.4 | 7.0 | 8.3 | 9.6 | 11.0 | 12.3 | 13.8 | 15.2 | 16.6 |
| 26° | 1.4 | 2. | 4.3 | 5.8 | 7.2 | 8.6 | 10.1 | 11.5 | 13.0 | 14.4 | 16.0 | 17.4 |
| 27° | 1.4 | 3.0 | 4.5 | 6.1 | 7.5 | 9.0 | 10.6 | 12.0 | 13.6 | 15.2 | 16.6 | 18.2 |
| 28° | 1.6 | 3.2 | 4.6 | 6.4 | 7.8 | 9.4 | 11.0 | 12.6 | 14.1 | 15.7 | 17.4 | 18.9 |
| 29° | 1.6 | 3.2 | 5.0 | 6.6 | 8.2 | 9.8 | 11.5 | 13.1 | 14.7 | 16.5 | 18.4 | 19.7 |
| 30° | 1.7 | 3.4 | 5.1 | 6.9 | 8.6 | 10.2 | 12.0 | 13.6 | 15.4 | 17.1 | 18.9 | 20.5 |
| 31° | 1.7 | 3.5 | 5.3 | 7.2 | 9.0 | 10.7 | 12.5 | 14.2 | 16.0 | 17.8 | 19.5 | 21.3 |
| 32° | 1.7 | 3.7 | 5.6 | 7.4 | 9.3 | 11.0 | 13.0 | 14.9 | 16.6 | 18.6 | 20.6 | 22.2 |
| 33° | 1.9 | 3.8 | 5.6 | 7.7 | 9.6 | 11.5 | 13.4 | 15.4 | 17.3 | 19.2 | 21.1 | 23.2 |
| 34° | 1.9 | 4.0 | 5.9 | 8.0 | 10.1 | 11.2 | 13.9 | 15.8 | 17.9 | 20.0 | 21.9 | 24.0 |
| 35° | 2.1 | 4.2 | 6.2 | 8.3 | 10.2 | 12.3 | 14.5 | 16.6 | 18.5 | 20.6 | 22.9 | 24.8 |
| 36° | 2.1 | 4.3 | 6.6 | 8.6 | 10.9 | 13.0 | 15.2 | 17.1 | 19.4 | 21.4 | 23.7 | 25.8 |
| 37° | 2.2 | 4.5 | 6.7 | 9.0 | 11.0 | 13.3 | 15.5 | 17.9 | 20.0 | 22.2 | 24.5 | 26.9 |
| 38° | 2.2 | 4.6 | 7.0 | 9.3 | 11.5 | 13.7 | 16.2 | 18.4 | 20.8 | 23.1 | 25.4 | 27.8 |
| 39° | 2.4 | 4.8 | 7.2 | 9.6 | 12.0 | 14.4 | 16.8 | 19.2 | 21.6 | 24.0 | 26.4 | 28.8 |
| 40° | 2.4 | 5.0 | 7.5 | 9.9 | 12.5 | 14.9 | 17.4 | 20.0 | 22.4 | 24.8 | 27.4 | 29.8 |



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The elevation

$$H_2 + \frac{c_2}{2}$$

gives the shot $P_3$, whose measured deviation is $c_3$.

By similar reasoning, the mean deviation of 3 shots, 1 actual and 2 fictitious, is $\frac{c_3}{3}$.

**395.** Because of the usual inaccuracy in measuring deviations and the possible intervention of systematic variations, this method gives only approximate results, and can not be carried through an indefinitely long series.

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## APPENDIX 4.

## USE OF METEOROLOGICAL DATA.

**396. Sources of meteorological data.**—In the French service, these are:

(*a*) Army stations (1 per army).

(*b*) Corps stations (1 per corps).

(*c*) Special stations for long range guns.[1]

(*d*) Certain battalions and batteries may be supplied a barometer and thermometer enabling them, if necessary, to calculate the air density.

**397. Nature of the meteorological data supplied.**—(*a*) Temperature and barometer for the mean altitude of the region, which is stated each time.

(*b*) Ballistic wind for maximum ordinates of 0,[2] 500, 1,000, 1,500, 2,000, 3,000, 4,000, and 5,000 meters.[3]

**398. Use** (par. 43 and seq.).—(*a*) Calculate the correction for air density (par. 43).

Data from the army stations gives the weight of a liter of air corresponding to a relative humidity of $\frac{1}{2}$ (old tables) or $\frac{3}{4}$ (new tables). The weight calculated by the corps stations is based on the actual hygrometric state.

**399.** (*b*) Calculate the wind correction as follows:

Choose the data for the maximum ordinate corresponding to the range used.

From the firing tables, calculate the deflection and range corrections for the lateral and longitudinal wind components, respectively, taken with respect to the line of fire.

---

[1] Artillery units ordinarily supplied by the army and corps stations may be at times supplied by special stations of near-by battalions of Heavy Artillery.

[2] On the ground.

[3] At times the actual wind is given, in which case it is specifically so stated. The direction from which the wind blows is measured from the Lambert north or the true north by the east, from 0 to 40 decagrades. For example, a wind from the east is 10. No wind is 00.



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**400.** For trajectories whose maximum ordinate is less than 500 meters, use the data for 500 meters.

For maximum ordinates less than 1,500 meters, use the corps data in preference to the army data, because of local variations in the lower atmospheric strata.

When the data available does not extend to maximum ordinates sufficiently high, use that for the highest ordinate given.

**401.** Data is supplied every four hours, day and night, beginning at an hour fixed for each army by general headquarters.

### USE OF THE BAROMETER AND THERMOMETER.

**402.** The aneroid barometer is a delicate instrument. It must be kept a sufficient distance from the pieces to protect it from shock.

It should be frequently compared (every 2 or 3 days), by telephone, with the barometer of the meterological station, correction being made for the difference in altitude.[1]

**403. Thermometer.**—The thermometer should be placed in the shade. It is best used by whirling it like a sling at the end of a string about a half meter long.

**404.** Calculate the weight of a liter of air by means of the charts in the firing tables. A slight error is made due to the fact that the true hygrometric state is not considered.

---

[1] When an Artillery unit is at an altitude $h'$ different than that $h$ for the data furnished, the barometer H′ may be computed from that given, H, by the following:

$H' = H + .09\,(h - h')$, if $h$ is greater than $h'$.

$H' = H - .09\,(h' - h)$, if $h$ is less than $h'$.

If the difference in altitude is more than 100 meters, obtain the barometer correction from the meteorological station.

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## APPENDIX 5.

## BALLISTIC WIND.

**405. Definition.**—The ballistic wind is a fictitious wind, constant in direction and velocity, which will have the same total effect on the flight of the projectile as the actual wind, which varies in direction and velocity in the different atmospheric strata through which the projectile passes.

**406. Determination.**—It is assumed that the disturbing action of a wind, constant in direction and velocity, on a layer of air of given thickness, say 500 meters, is proportional to the time of passage of the projectile through this layer.

**This assumption is not strictly correct,** but it gives a first approximation.

Let $T_1, T_2 \ldots ., T_n$ be the times of flight of the projectile through the successive layers of air each 500 meters thick. In each of these layers, the wind obtained by direct observation is assumed to be constant in direction and velocity.

Let T be the time of flight.

$V_1, V_2 \ldots ., V_n$ the longitudinal (lateral) wind component in the various layers.

By taking the weighted mean of the wind components in the various layers, the corresponding component of the ballistic wind as previously defined is

$$V = V_1 \frac{T_1}{T} + V_2 \frac{T_2}{T} + \ldots + V_n \frac{T_n}{T}.$$

Now it can be verified that the ratios

$$\frac{T_1}{T}, \frac{T_2}{T} \ldots , \frac{T_n}{T}$$

are constant for all trajectories of the same maximum ordinate, regardless of the eleveation, muzzle velocity, caliber, kind of projectile, etc.



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A study of the various trajectories further shows that if

$$T_{\frac{1}{4}},\ T_{\frac{1}{2}},\ \text{and}\ T_3$$

be the times passed by the projectile above the altitudes respectively

$$\frac{F}{4},\ \frac{F}{2},\ \frac{3F}{4}$$

F being the maximum ordinate, then

$$\frac{T_{\frac{1}{4}}}{T}=.87,\quad \frac{T_{\frac{1}{2}}}{T}=.74,\quad \frac{T_{\frac{3}{4}}}{T}=.51$$

regardless of the elevation, muzzle velocity, caliber, and kind of projectile.

This property is general. If $T_{pn}$ is the time passed by the projectile above the altitude $\frac{pF}{n}$ then $\frac{T_{pn}}{T}=K_p$.

$K_p$ being a numerical coefficient.

This and similar coefficients for the various layers permit the determination of the ratios

$$\frac{T_1}{T},\ \frac{T_2}{T},\ \ldots\ldots\ \frac{T_n}{T}$$

entering into the general expression for the ballistic wind component V, previously given.

To illustrate, take the case where $n=4$:

$$\frac{T_4}{T}=\frac{T_{\frac{3}{4}}}{T}=.51$$

$$\frac{T_3}{T}=\frac{T_{\frac{1}{2}}}{T}-\frac{T_{\frac{3}{4}}}{T}=.71-.51=.20$$

$$\frac{T_2}{T}=\frac{T_{\frac{1}{4}}}{T}-\frac{T_{\frac{1}{2}}}{T}=.87-.71=.16$$

$$\frac{T_1}{T}=1-\frac{T_{\frac{1}{4}}}{T}=1-.87=.13.$$

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The expression for the ballistic wind component is then

$$V=.13V_1+.16V_2+.20V_3+.51V_4$$

**407.** Similarly it is possible to find by a study of the various trajectories the values of the coefficients in the general case of $n$ layers of air. It will be noted that the values thus obtained are essentially the same as those found analytically for the trajectory in vacuo.

Assuming on this basis that the trajectory in vacuo affords a sufficiently close approximation, and remembering that in this case

$$F=.5gT^2$$

the coefficient $K_p=\frac{T_{p/n}}{T}$ becomes $K_p=\frac{\sqrt{n-p}}{\sqrt{n}}$.

Thus

$$\frac{T_1}{T}=1-\frac{T_{1/n}}{T}=1-K_1=\frac{\sqrt{n}-\sqrt{n-1}}{\sqrt{n}}$$

$$\frac{T_2}{T}=\frac{T_{1/n}}{T}-\frac{T_{2/n}}{T}=K_1-K_2=\frac{\sqrt{n-1}-\sqrt{n-2}}{\sqrt{n}}$$

. . . . . .

$$\frac{T_n}{T}=\frac{T_{(n-1)/n}}{T}-\frac{T_{n/n}}{T}=K_{n-1}-K_n=\frac{1}{\sqrt{n}}.$$

The general expression for the ballistic wind component can then be written:

$$V=\frac{\sqrt{n}-\sqrt{n-1}}{\sqrt{n}}V_1+\frac{\sqrt{n-1}-\sqrt{n-2}}{\sqrt{n}}V_2+\ldots+\frac{1}{\sqrt{n}}V_n.$$

**408.** In practice, the ballistic wind components for the various maximum ordinates differing by 500 meters can be determined at the meterological stations in the following manner.

Determine by direct observation the direction and velocity of the wind in each of the various layers 500 meters thick.

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Resolve each of these observed values into components with respect to two axes, X and Y, arbitrarily chosen, as, for example, the Lambert north and the Lambert east.

The ballistic wind components for each of the axes is then computed by the general expression previously stated.

**COMPONENTS OF BALLISTIC WIND.**

| Maximum ordinate. | Lambert north. |
|---|---|
| 500 | $X_1$ |
| 1000 | $\frac{\sqrt{2}-\sqrt{1}}{\sqrt{2}} X_1 + \frac{1}{\sqrt{2}} X_2$ |
| 1500 | $\frac{\sqrt{3}-\sqrt{2}}{\sqrt{3}} X_1 + \frac{\sqrt{2}-\sqrt{1}}{\sqrt{3}} X_2 + \frac{1}{\sqrt{3}} X_3$ |
| 2000 | $\frac{\sqrt{4}-\sqrt{3}}{\sqrt{4}} X_1 + \frac{\sqrt{3}-\sqrt{2}}{\sqrt{4}} X_2 + \frac{\sqrt{2}-\sqrt{1}}{\sqrt{4}} X_3 + \frac{1}{\sqrt{4}} X_4$ |
| 2500 and so on. | |

| | Lambert east. |
|---|---|
| 500 | $Y_1$ |
| 1000 | $\frac{\sqrt{2}-\sqrt{1}}{\sqrt{2}} Y_1 + \frac{1}{\sqrt{2}} Y_2$ |
| 1500 | $\frac{\sqrt{3}-\sqrt{2}}{\sqrt{3}} Y_1 + \frac{\sqrt{2}-\sqrt{1}}{\sqrt{3}} Y_2 + \frac{1}{\sqrt{3}} Y_3$ |
| 2000 | $\frac{\sqrt{4}-\sqrt{3}}{\sqrt{4}} Y_1 + \frac{\sqrt{3}-\sqrt{2}}{\sqrt{4}} Y_2 + \frac{\sqrt{2}-\sqrt{1}}{\sqrt{4}} Y_3 + \frac{1}{\sqrt{4}} Y_4$ |
| 2500 and so on. | |

The components thus obtained can then be combined for each maximum ordinate. The resultants are the ballistic winds in direction and velocity.

In actual practice, the meteorological stations employ charts or other means which greatly abbreviate the process just outlined.

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# PART II.

# RECONNAISSANCE.

## APPENDIX 6.

## PROCEDURE IN RECONNAISSANCE.

### GENERAL REMARKS.

**409.** Every reconnaissance begins with a study on the map or battle map of the area to be reconnoitered. This study coordinates subsequent work and saves time.

The reconnaissance personnel should in every way possible get in touch with the commanders of units which have occupied or are occupying the region itself or its vicinity. The experience of these officers can thus be utilized to advantage.

These preliminary steps do not ordinarily obviate the necessity for artillery commanders going over the ground themselves and personally supervising the units under their orders.

### BY CORPS AND DIVISION ARTILLERY COMMANDERS.

**410.** Such reconnaissances are to fix the general conditions of the entry into action of the large artillery units.

They are made conjointly with those of the corps and division commanders.

Corps and division artillery commanders must be perfectly informed as to the nature and condition of the ground, the communications, and the defilade, in order to be able themselves to direct the march, deployment, entry into action, and supply of their respective units.

The reconnaissance of the terrain as a whole, the objectives, and the observing sectors are made by the artillery commanders with the assistance of their staffs, immediately upon receipt of information as to the engagement of their units.

Reconnaissances of command observation posts, command posts, and liaisons are made as soon as the situation permits.



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### BY REGIMENTAL AND GROUP COMMANDERS.

**411.** Each regimental and group commander receives instructions from the corps or division artillery commander as to:

The general situation.
His mission.
The conditions of his engagement.

He also receives instructions as to the location of the various Infantry and Artillery command posts, the routes to follow, and the liaisons to be established.

### OBJECT.

**412.** The object of the reconnaissance is to determine:

Suitable positions and their zones of action.
The routes of access.
Regimental or group command and command observation posts.
The approximate positions of the terrestrial observation posts.
The plan for telephonic liaisons.

In addition, the regimental or group commander should establish relations as soon as possible with the infantry commander whom he has to support.[1]

### EXECUTION.

**413.** Depending on the instructions and information received, the regimental (group) commander studies:

The assignment of battalions to the different missions.
The conditions of engagement of these battalions.

**414.** After having given orders for the continuation of the march and the reconnaissances desired, the regimental commander sets out on his reconnaissance accompanied by:[2]

The reconnaissance officer.
The telephone officer.
The battalion agents.[3]
The necessary orderlies.

---

[1] Or with the artillery commander of this infantry unit in the case of a group to counterbattery artillery.
[2] If he deems advisable, he may take one or several battalion commanders.
[3] If the reconnaissance is by automobile, the agents remain at the command post.

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As soon as he has selected positions for the battalions, the routes of access, and his command post, the regimental commander summons his battalion commanders and gives them the necessary instructions.

He then sends for the detail and its vehicles and makes a brief report to the next higher commander on the dispositions made.

**415.** Upon the arrival of the telephone, topographic, and radio matériel, and in accordance with the instructions of the regimental commander:

The **radio officer** establishes the radio station.

The **reconnaissance officer** reconnoiters and establishes the regimental command and command observation posts.

The **telephone officer** installs the lines connecting the various infantry and artillery command posts.

### BY BATTALION COMMANDERS.

**416.** Each battalion commander receives instructions from his regimental (group) commander as to:

The general situation.
His mission and zone of action.
The position.
Its routes of access.
The time of opening fire.
The locality for the battalion observation post and its sector.
The liaisons necessary.
The location of the various infantry and artillery command posts.

### OBJECT.

**417.** The object of the battalion commander's reconnaissance is to determine:

The battery positions.
The routes of access.
The battalion observation post and the objectives.
The battalion command post.
The telephone and optical liaisons.

When appropriate, the battalion commander enters into relations as soon as possible with the infantry commander whom he has to support.

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### SUBDIVISION OF THE RECONNAISSANCE PARTIES.

**418. First party.**
Battalion commander.
Reconnaissance officer.
Telephone officer.
Scouts and battery agents.
Instrument noncommissioned officer.

**Second party.**
Battery commanders.[1]
The commander of the combined combat trains.
The battery details.[2]

**Third party.**
Radio officer.
Surgeon.
Battalion and battery telephone details.
Transportation of telephones and topographic matériel.

Depending on circumstances and the instructions of the battalion commander, the third party marches with the first party or slightly in rear, or with the second party. (In tractor artillery, the telephone officer usually marches with the third party.)

### EXECUTION.

**419.** As soon as he has received his instructions from the regimental (group) commander, the battalion commander starts on his reconnaissance with the first party. Before leaving, he gives the necessary orders covering:

The timely arrival of the second and third parties.

The continuation of the march of the column, its route and the method of marking it, the limit of advance of the column, the point where it will receive new orders, the post of the ammunition section or combat trains.

**420.** On arriving in the vicinity of the position, the battalion commander halts the party under cover. He then makes a reconnaissance, with only the personnel absolutely necessary, including:

---

[1] If one of the battery commanders is left in command of the column, his place is taken by the senior lieutenant.

[2] The battery reconnaissance instruments and matériel are disposed as directed by the battery commander.

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The selection of battery positions.[1]
The study of routes of access, their defilade, and work necessary on them.
The selection of an observation post, the reconnaissance of objectives, and if necessary the area for the battery observation posts.
The selection of the command post.

**421.** After this reconnaissance, the battalion commander gives the necessary orders to bring up the second and third parties and the column.

He then reconnoiters a position for the trains and decides on the location of the telephone lines.

He renders a report to the regimental (group) commander as to the dispositions made and the approximate time of opening fire.

**422. Duties of the reconnaissance officer.**—The reconnaissance officer makes the necessary determinations in regard to the battery positions.

He accompanies the battalion commander when the latter selects his observation post, and locates it accurately on the map. He determines an origin line and identifies a certain number of known points. These are plotted on a rough sketch.

He then determines for the battalion, or for each of the batteries, an orienting line; and also the coordinates of one or more place marks which will enable the prompt location of the base pieces.

Before the batteries go into position, the reconnaissance officer furnishes each battery commander in writing such information as is immediately necessary, particularly that pertaining to the establishment on the base line, determines their origin lines, and makes panoramic sketches for them.

He then accurately locates the observation posts.

**423. Duties of the telephone officer.**—Upon the arrival of the third party, the telephone officer supervises the installation of the telephone system and the laying of such lines as involve the battalion telephone equipment.

**424. Duties of the radio officer.**—The radio officer causes the installation of the radio equipment and supervises the operation of the radio station and that at the battalion command post.

[1] When time is important, the reconnaissance of positions and routes of access may consist simply of general indications, the battalion commander occupying himself at once with the selection of an observation post and the reconnaissance of objectives.



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**425.** The **surgeon** reconnoiters a site for the aid station and supervises its organization.

### BY BATTERY COMMANDERS.

**426.** The second party, on arrival, halts where the first party was halted by the battalion commander.

The battery commanders and the train commander approach the battalion commander, who gives them instructions as to the following:

The general situation.
The battery positions and their routes of access.
The mission of each battery, its field of action, and its base point.
The position of the battalion observation post, and sometimes the locality for the battery observation posts.
The time of opening fire.
The telephone and optical liaisons to be established.
The distribution among the batteries of the construction necessary (installation of the telephone system, the construction of the battalion command and observation posts and of the aid station, etc.).
The positions for the trains.

**427.** Each battery commander then:

Definitely locates the positions for the pieces.
Carefully reconnoiters the routes of access to the position.
Selects an observation post.

He sends the executive officer the necessary instructions for occupying the position.

He arranges for the personnel and tools for the necessary work in connection with organizing and constructing the position and the observation post, improving the roads, and clearing the field of fire.

He then locates his command post and the dugouts, arranges for the installation of such telephone lines as pertain to the battery, and takes the necessary steps to insure supply.[1]

[1] Careful provision should be made for supplying hot food to the personnel at the battery position. This is very necessary, as these men are subjected to severe fatigue and often deprived of sleep.

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**If time is important,** the battery commander selects an observation post at once and proceeds to the preparation of fire. In this case, the executive officer puts the battery in position.

**428.** The commander of the trains reconnoiters the position for his units, and decides on the routes of supply. He arranges for traffic regulation.

**429.** The reconnaissance is completed as soon as possible by a study of the close defense of the position, such as machine-gun emplacements and small-arms ammunition supply, as well as the necessary measures for the use of them and other available means.

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# PART III.

## OBSERVATION.

### APPENDIX 7.

### UNILATERAL OBSERVATION.

**430.** The adjustment in the case of unilateral observation consists of the following:

(*a*) Bringing the shot on the observing line, either by firing or by appropriate changes of data.

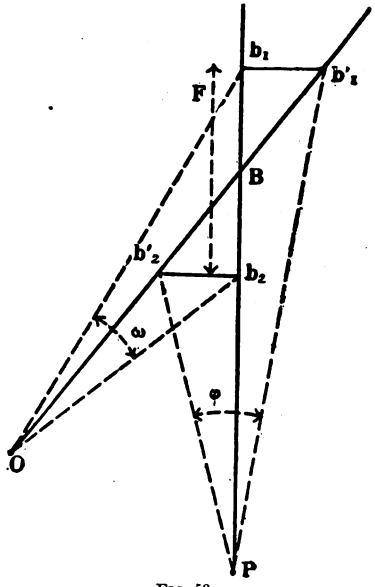


FIG. 53.



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(*b*) Trial fire.
(*c*) Improvement fire.
During (*a*) and (*b*), the shots must be maintained in the general case, on or near the observing line, by compensating changes in deflection and elevation.

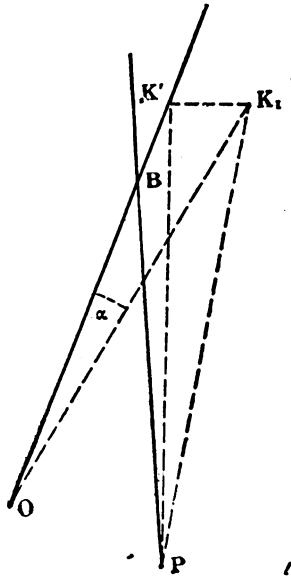


FIG. 54.

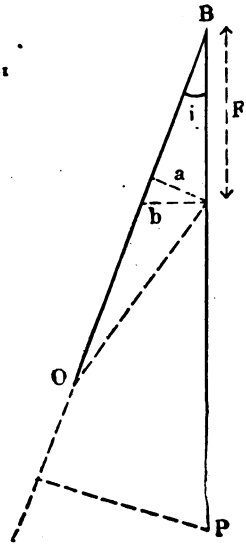


FIG. 55.

**431. Preliminary operations.**—Plot the base piece P (fig. 53), observation post O, and adjusting point B.
Draw the line OB and PB.

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On the line PB, lay off $Bb_1$ and $Bb_2$ each equal to a half fork. At $b_1$ and $b_2$ erect perpendiculars to PB. These intersect OB at $b'_1$ and $b'_2$.

Let $\omega$ be the angle $b_1Ob_2$, and $\phi$ the angle $b'_1Pb'_2$.

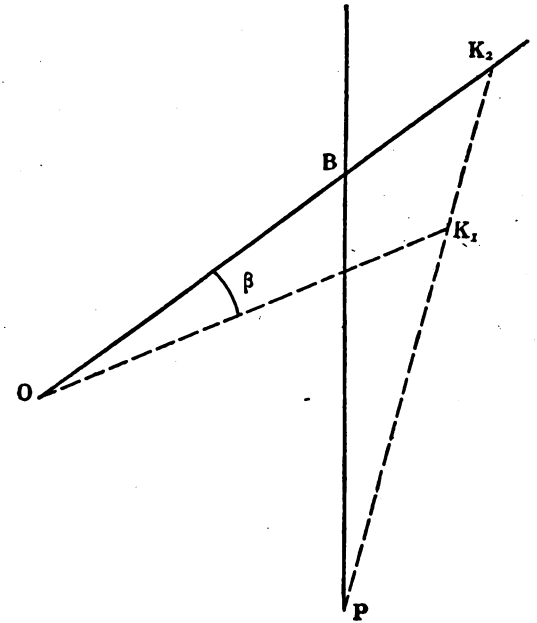


FIG. 56.

$\phi$ is called the **lateral fork,** and is the deflection change necessary to keep the shot on the observing line when the range is changed by one fork.

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### TRIAL FIRE.

**432.** Bringing the shot on the observing line and trial fire are executed in a manner which depends on whether the observer displacement is less or greater than 300 mils (pars. 96 and 105).

**433. First case.—Observer displacement less than 300 mils** (fig. 54).

Fire two shots with the determined data. The center of these shots will not in general be on the observing line. Measure the angular deviation $\alpha = K_1OB$.

To bring the center on the observing line, a **deflection** change of $K_1PK'$ is necessary. An approximate value of this change is

$$\alpha \times \frac{\phi}{\omega}$$

$\frac{\phi}{\omega}$ being calculated in advance.[1]

If this change does not bring the center of the next two shots on the observing line, the new center is treated in the same manner as the first one $K_1$. Let K be the first shot sensed on the observing line.

**434.** Trial fire is then executed, using **elevation** bounds of one fork F.

---

[1] When the observation post is not too close to the objective, $\frac{\phi}{\omega}$ can be determined by the following approximate method (fig. 55):

$$\text{Tan } \phi = \frac{b}{BP}, \text{ approximately}$$

$$\text{Tan } \omega = \frac{a}{OB}$$

$$\frac{\phi}{\omega} = \frac{b}{a} \times \frac{OB}{PB}$$

$$a = b \cos i$$

$$\text{Therefore } \frac{\phi}{\varepsilon} = \frac{OB}{PB \cos i}$$

$$\text{Or } \frac{\phi}{\omega} = \frac{\text{Distance OB}}{\text{Projection of PB on OB}}$$

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For each bound of one fork it is necessary to change the deflection by one lateral fork. The fire is continued until a verified bracket of one fork has been obtained.

**435. Second case.—Observer displacement greater than 300 mils** (fig. 56).

Fire two shots with the determined data. The center of these shots $K_1$ will not in general be on the observing line. Measure the angular deviation $\beta = K_1OB$.

To bring the center on the observing line, an elevation change corresponding to $K_1K_2$ is necessary. An approximate value of $K_1K_2$ is $\beta \times \frac{F}{\omega}$.

$\frac{F}{\omega}$ is calculated in advance.[1]

If this change does not bring the center of the next two shots on the observing line, the new center is treated in the same manner as the first one. Let K be the first shot sensed on the observing line.

**436.** It is possible that the changes thus determined will be found uniformly too large or too small.

In this case, it is concluded that there is an error in deflection.

The elevation changes determined by $\beta \times \frac{F}{\omega}$ will be too large when the line of fire passes between the objective and the observation post[2] (fig. 58).

---

[1] For the true value of $\omega$ is then greater than the value used in computing $\frac{F}{\omega}$.

[2] $\beta$ and $\omega$ should be taken in the same angular unit.

The following is an approximate method of determining $\frac{F}{\omega}$, $\omega$ being measured in mils and F in meters (fig. 57):

$$a = F \sin i$$

$$F = \frac{a}{\sin i}$$

$$a = OB \sin \omega = \frac{OB\,\omega}{1{,}000}$$

$$\omega = \frac{1{,}000\,a}{OB}$$

$$\frac{F}{\omega} = \frac{OB}{1{,}000 \sin i} = \frac{OB}{1{,}000} \times \frac{OB}{OK}.$$

Or $\frac{F}{\omega}$ = OB in km. × the ratio to the distance of O from PB.

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The changes will be too small when the line of fire passes on the opposite side of the objective from the observation post.

In this case, the deflection should be modified to correct for this discrepancy, according to the principles of paragraph 433.

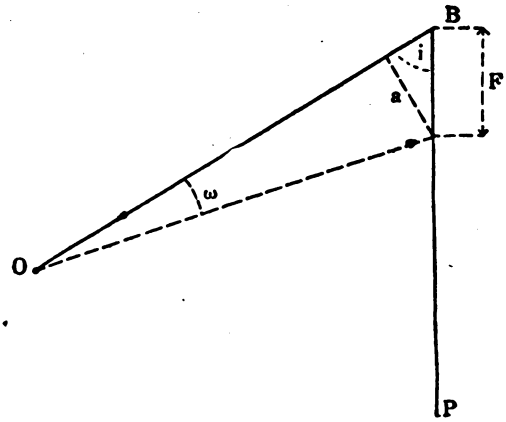


FIG. 57.

**437.** As soon as the shots have been brought onto the observing line, trial fire is executed, using elevation bounds of one fork, F.

For each change in elevation, a corresponding deflection bound should be made, equal to one lateral fork.[1]

The adjutment is continued until a verified bracket of one forks is obtained.

[1] If the lateral fork exceeds 16 mils, the elevation bound should be reduced to keep the deflection bound within this value.

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**438.** If the deflection is materially in error, bringing the shots on the observing line by elevation changes may carry the fire a considerable distance from the objective. If the latter is close to the friendly line, the fire may be dangerous.

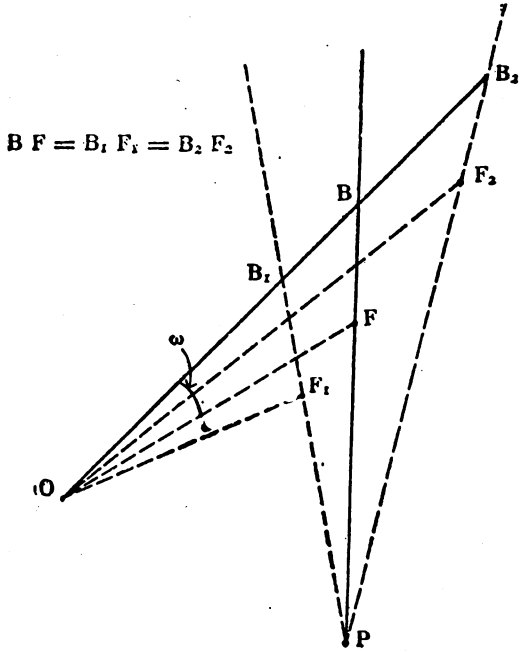


FIG. 58.

In this case, depending on the reliability of the initial deflection determination, it is advisable to bring the first shots on the observing line by deflection instead of elevation changes.

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### IMPROVEMENT FIRE.

**439.** The bracket of one fork having been obtained, as previously described, the objective is very probably in the zone of dispersion of the midrange of the bracket. The shots establishing the limits of

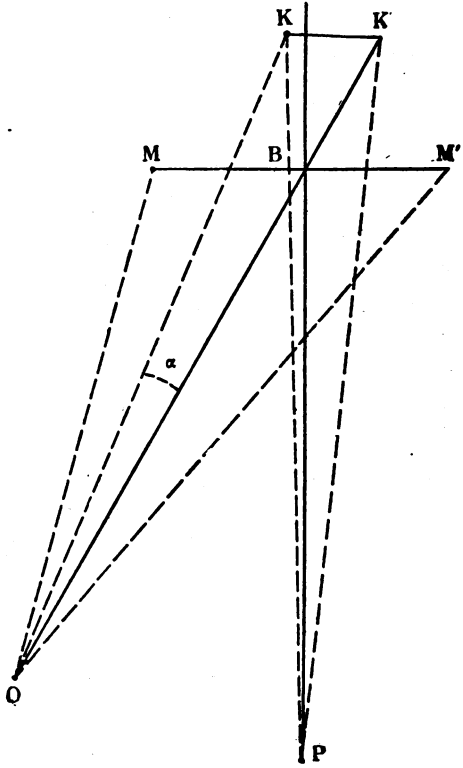


FIG. 59.

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the bracket, being on the observing line, will have different deflections, thus establishing a deflection as well as a range bracket. Improvement fire should be at the middle of both the range and deflection brackets.

The deflection thus obtained should be nearly correct. For this reason, for an observer on the right (left) of the line of fire, all shots to the right (left) of the observing line are taken as over, and all shots to the left (right) are taken as short.

The adjusted elevation is determined in the usual manner (par. 219). This principle is also applicable to the deflection adjustment.

**440.** Much information in regard to the deflection adjustment can be derived from a record of the deflection changes during trial fire and improvement fire.

It should be remembered that a shot on the observing line sensed over against the objective is to the left (right) of the objective from the position of the piece, when the observer is to the right (left) of the line of fire. A shot on the observing line sensed short against the objective is to the right (left) of the objective from the position of the piece, when the observer is to the right (left) of the line of fire.

**441.** If the objective has width, as viewed by the observer, shots in the observing sector can be observed for range even though not on the observing line. They can also be used in the deflection adjustment as follows (fig. 59):

Let MM′ be an objective whose adjusting point is B.

Let K be a shot fired with the deflection $d$, sensed over and $\alpha$ left of B.

A deflection change of $\alpha \times \frac{\varphi}{\omega}$ would bring the shot to K′, which would be to the right of the objective from the position of the piece. The shot K′ need not actually be fired, but the deflection for it should be noted as being to the right of the objective. This deflection should be the one to which the lateral fork is applied when the elevation is changed by one fork. The shots at the new elevation should then be on the observing line.

This also applies to shots which are sensed, even though they are out of the observing sector.

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## APPENDIX 8.

### BILATERAL OBSERVATION.

**442.** Bilaterial observation consists in the measurement of the angular deviations of the bursts, either air or graze, with respect to an adjusting point, by two lateral observers. These deviations are transmitted to the battery, and serve as a basis for calculating the deviations in range and deflection.

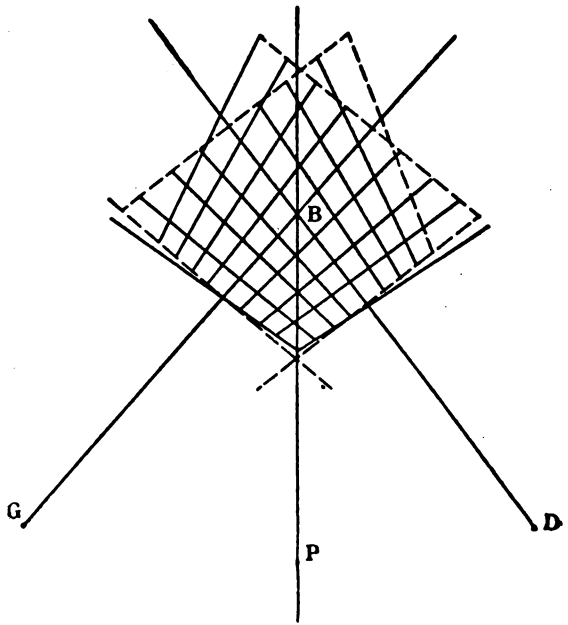


FIG. 60.



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Bilateral observation may be by :

(*a*) Graphical method.

(*b*) Index method.

**443. Graphical method.**—The base piece P (fig. 60), the adjusting point B, and the two observation posts D and G are plotted on the map. Draw the lines BD and BG.

Starting at BD, lay off lines radiating from D at intervals of 10 mils and extending say 500 meters in both directions from B.

Construct a similar scale with respect to GB.

This construction may be on a separate sheet to a large scale, the lines GB, PB, and DB being transferred by means of the map squares.

This chart enables the position of a shot to be plotted at once by means of the observations sent in by the two observers.

The fire is conducted by the usual methods (pars. 215 and 219 or 228). Range and deflection scales on the chart with respect to the piece will facilitate reading the changes necessary.

**444.** The accuracy of plotting the bursts may be increased by using three observers. The intersection of the three observations on a burst forms a triangle of error, which gives an idea of the reliability of the observations.

The observers may refer their measurements to any origin lines instead of to an adjusting point. In this case the origin lines must be accurately plotted. The chart for plotting shots is then constructed on them.

### INDEX METHOD.

**445. Range adjustment.**—A **right** (left) deviation for the **right** (left) observer is taken as positive (+). A **left** (right) deviation for the **right** (left) observer is negative (−). In other words, the deviation is positive when it is the same as the position of the observer, and negative when it is opposite to the position of the observer.

The algebraic sum of the two reported deviations is called the **index** of the shot.

A positive index means that the shot is over; a negative index, that it is short. A zero index means that the burst is at the range of the adjusting point.

**446. Deflection adjustment.**—The following is an approximate rule: From the deviation reported by the **right** (left) observer sub-

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tract algebraically the deviation reported by the left (right) observer, when the matériel is such that an increase of deflection carries the shot to the left (right). Add **one-half** of this difference to the deflection.

**Examples.**—The 75:

(*a*) Right observer reports: Right 20, right 20.
Left observer reports: Right 10, right 10.

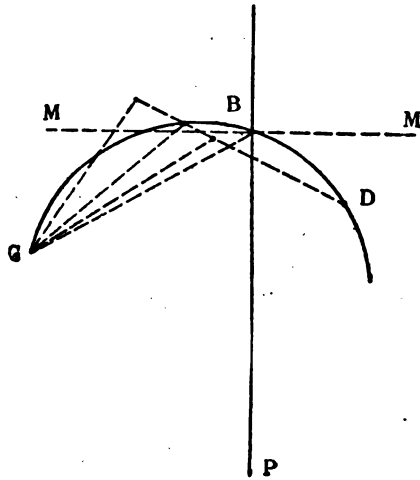


FIG. 61.

The shots are over, since $20+(-10)=+10$. The deflection change should be

$$\frac{20-(-10)}{2}=+15$$

howing that the shots were to the right.

(*b*) Right observer reports: Right 10, right 10.
Left observer reports: Left 4, left 4.

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The shots are over, since $10+(+4)=+14$. The deflection change should be

$$\frac{10-(+4)}{2}=+3$$

showing that the shots were to the right.

**447. Method of fire.**—A bracket adjustment is obtained and zone fire for effect used (pars. 229 and 257).

The size of the bracket sought decreases with the accuracy of the observations, the proximity of the observers to the objective, and the distance between the observers. The observers should be as nearly symmetrically placed with respect to the line of fire as possible.

The bracket is always verified (par. 215).

**448. Significance of the index.**—Draw MM′ perpendicular to the line of fire at the objective B (fig. 61). Construct a circle passing through G, B, and D. The rule stated in praagraph 446 is based on the following:

Points outside of the circumference have a positive index, as can be seen from the figure, and are taken as over.

Points inside of the circumference have a negative index and are taken as short.

Points on the circumference have a zero index and are taken as at the range of the objective.

The rule stated for practical use will be in error then for points which are between the circumference and the line MM′. It is evident that such errors will occur less frequently when the two observers are symmetrically placed with respect to the line of fire, than when they are widely separated.

**449. Deflection deviations.**—The rule stated in paragraph 446 is strictly correct only when the observers are symmetrically placed with respect to the line of fire.

Construct a circle (fig. 62) passing through G, B, and D. Let K be the point of burst. Suppose the piece to be on the circumference.

Barring a serious error in deflection determination, the line PK will be near PB, and the point M will be near the middle of the arc



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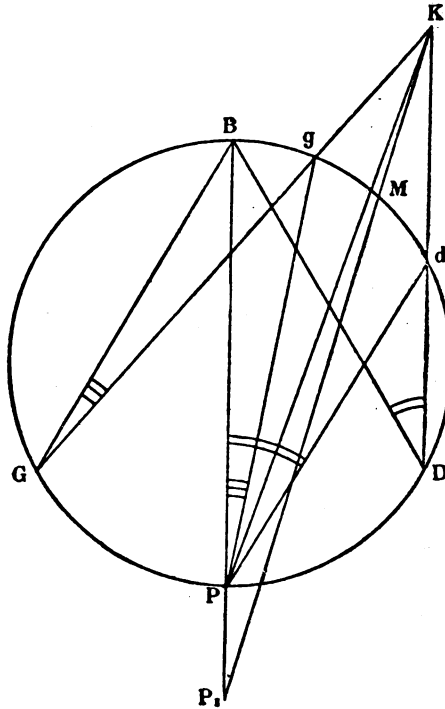


FIG. 62.

GBD. It may be assumed then, without serious error, that the deflection change necessary, BPK, is

$$\frac{BPd+BPg}{2}$$

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This is the same as the change called for by the rule which is

$$\frac{BDd-(-BGg)}{2}$$

by the principle of inscribed angles.

For a position of the piece, $P_1$, outside of the circumference, it is necessary to multiply the deflection change found by the rule by the ratio

$$\frac{BP}{BP_1}.$$

**450.** The symmetry of the two observation posts with respect to the line of fire is not indispensable to the use of bilateral observation without maps, but it is of material advantage in reducing the depth to be covered in fire for effect. This condition does not enter into firing by using the map.

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# PART IV.

## PREPARATION OF FIRE.

### APPENDIX 9.

### ADVANTAGE OF AN ORIENTING LINE.

**451.** Formerly the indirect fire of a piece P on an objective O was accomplished as follows: The range was measured directly on the map or determined topographically. In laying for direction a known aiming point was used. The sight was set so that when the

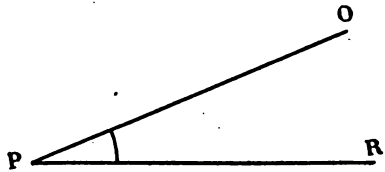


FIG. 63.

plane of sight was directed on the aiming point, the piece was directed at the objective (or the base point).

The firing angle in this case (par. 142) was measured with the protractor after plotting the points O, P, and R by their coordinates.

**452.** This method does not give sufficient accuracy in deflection for the present conditions. The direction of PO can usually be determined with sufficient accuracy, because O is ordinarily quite distant. But this is not generally true in regard to PR.

To be visible from the piece, R is usually close. Moreover P and R are not often known beforehand and must be located at the time. This frequently involves difficult and protracted topographical operations, sometimes quite distant from the battery.



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Practically, the plotted direction PR is usually materially in error,[1] and the deflection is correspondingly in error.

**453.** The necessary accuracy in laying for direction can readily be obtained if, instead of locating the points P and R, the direction PR is directly determined by means of instruments which are supplied to Artillery units.[2]

If PR is taken through the sight of the piece, it is necessary that the piece be in position before the determination of PR, or that the

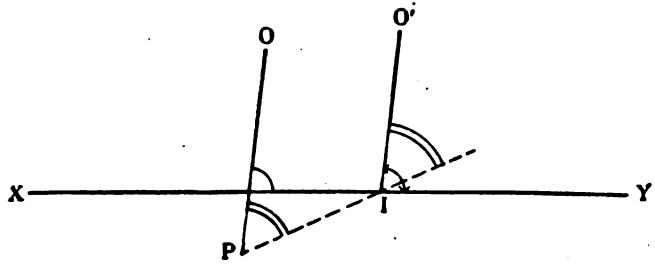


FIG. 64.

position of the sight be accurately marked and later occupied by the piece. The preparation of fire can not usually await the arrival of the battery, but should begin as early as possible during the reconnaissance.

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[1] An error of 20 meters in the location of P and R is not unusual. Such errors result from errors in the location of the points by which P and R are located, of errors in the operations performed, and graphical errors. If the errors in P and R are in opposite directions, the error in the direction PR will be 100 mils if the distance PR is 400 meters; 40 mils if PR is 1,000 meters, and 20 mils if PR is 2,000 meters. A rapid preparation of fire without previous organization will involve even more considerable errors when this method is used; so that recourse should be had to other methods.

[2] It may be taken that the error of initial deflection determination should not exceed:

10 mils for light guns and for howitzers.
5 mils for heavy guns.
2 mils for high-power guns.

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**454.** It is better not to use PR in laying for direction, but instead to select a line merely passing conveniently near the piece, and no through it.

The direction of this line, the orienting line, is directly determined, and plotted as a direction, not for position. The line PO is determined, as previously, by the position of the points P and O.

Laying for direction is effected by setting an instrument, I (fig. 64), at any convenient point on the orienting line, XY. The 0 of the instrument is pointed in the direction IO′ parallel to PO, as described in paragraph 147. The piece is then laid in the direction PO by reciprocal laying (par. 148).

**455.** The use of the orienting line as herein contemplated has other advantages than the saving of time in the accurate preparation of fire.

It is a general method, and is particularly applicable to the not infrequent case where a distant aiming point can not be used.

The orienting line is permanent, and still utilizable when for any reason the pieces are moved for short distances.

The determination of the orienting line is facilitated by its being independent of the pieces. If a declinated instrument is used in its determination, it may be set up at points not near masses of iron. Several points can be used to check results and eliminate errors due to local attraction.

The orienting line can readily be common to two or more batteries, or even several battalions, and the advantages of a regular sheaf within a battery can thus be extended to many pieces.

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## APPENDIX 10.

## MAPS AND BATTLE MAPS.

**456.** The **scale** of a map is the ratio of a given distance on the map to the corresponding horizontal distance on the ground.

The scale of the various maps is as follows:

1/20000:1 mm.=20 meters; 5 cm.=1 km.
1/10000:1 mm.=10 meters; 10 cm.=1 km.
1/5000 :1 mm.= 5 meters; 20 cm.=1 km.
1/40000:1 mm.=40 meters; 25 mm.=1 km.
1/80000:1 mm.=80 meters; 12 mm. 5=1 km.

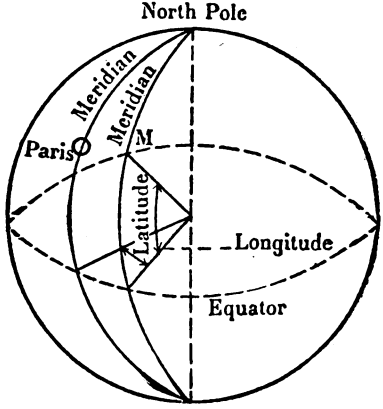


FIG. 65.

**457. Battle maps** (par. 116).—The colors used on battle maps are:

**Black or gray.**—Details of the terrain, such as water courses, roads, cultivation, buildings.

**Brown.**—The form of the terrain, by contours at 5 or 10 meters vertical interval.

**Blue.**—Enemy works.

**Red.**—Friendly works, or simply the line of the front.



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**458. Geographic coordinates.**—The **meridian plane** of a point, M, is the plane containing the axis of the earth and the point M.

The **meridian** of a point, M (fig. 65), is the intersection of its meridian plane and the earth's surface.

The **true** or **geographic north** is along the meridian.

A point on the earth's surface is defined by its geographic coordinates, longtiude and latitude.

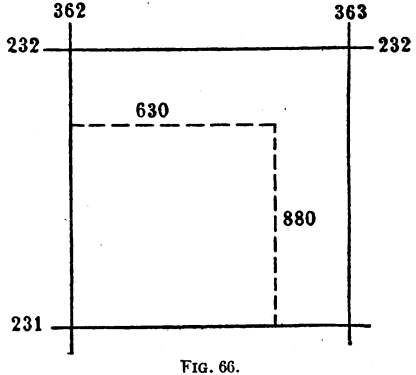


FIG. 66.

The **longitude** of a point is the angle formed by its meridian plane with the prime meridian plane taken as the origin of longitude. In France the prime meridian plane is that of Paris. Longitude is reckoned from 0 to 200 grades, east and west.

The **latitude** of a point is the angle made by the normal to the surface at this point with the plane of the Equator. Latitude is reckoned from 0 at the equator to 100 grades, north and south.

**459. Map squares and coordinates.**—All maps used in firing are provided with kilometer squares, called Lambert squares, which are numbered on the margin (and sometimes at the intersections).

A point is defined by its $x$ and $y$ coordinates, which are the distances of the point from the X and Y axes, respectively, of the map.

The **abscissae X** increase from left to right.

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The **ordinates Y** increase from bottom to top.

The Lambert, or Y-north, is the direction of the vertical lines of the map squares, from bottom to top, using the Lambert system of projection.

**460. Numerical designation of objectives.**—A point on the map may be designated by a number of four or six figures. The first two or three figures give the abscissa to the nearest hectometer, and the last two or three the ordinate.

Thus, the complete coordinates of the point shown in figure 66 are:

$$x=362.630$$
$$y=231.880$$

The numerical designation of this point would be 26.19, or 626.319 (hectometric coordinates).

This method is used only for the designation of objectives. To accurately define the position of the point the complete coordinates are used, thus:

$$x=362.630$$
$$y=231.880.$$

**461. Convergence of the meridians.**—In the Lambert system, the meridians are represented by straight lines converging toward the north. As a result, the geographic north and the Lambert north, or Y-line, do not coincide.[1]

The angle between these two directions is called the **convergence of the meridians.** Its value for a point whose longitude is M, east of Paris, is given by the following expressions:

In decigrades: $7.6 \times (M-6)$.
In mils: $12.16 \times (M-6)$.

If M is greater than 6, the Y-line is east of the meridian. If M is less than 6, the Y-line is west of the meridian.

**462. Y-azimuth.**—The Y-azimuth of a line OM is the angle between it and the Y-line, measured from the north clockwise from 0 to 6,400 mils, or 0 to 4,000 decigrades.

**463. Magnetic north—Declination.**—A magnetic needle oscillating freely points toward the **magnetic north**.

[1] Except for the meridian 6 grades east, which coincides with the Y-line for which $x=500{,}000$ m.

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The declination is the angular amount the **magnetic** north deviates from the **true** north (fig. 67) The Y-declination is the angular amount the magnetic north deviates from the Y-line.

The declination varies continually. At present, in France, it is west.

The declination charts give fairly accurate values of the declination.

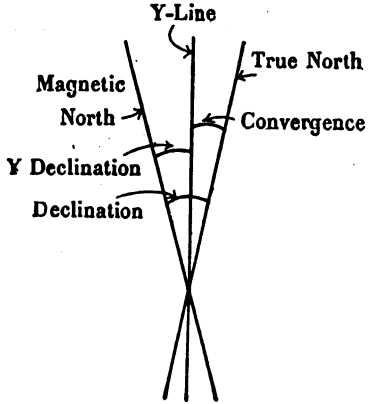


FIG. 67.

For points west of the meridian 6 grades east, the situation is as shown in figure 67.

**Triangulation system.**—This is a network of points, easily identified on the ground, and whose position is accurately known. Some are artificial or natural markers visible from a distance (steeples, smokestacks, trees, etc.). Others are simply stakes marking the points of a traverse.

The triangulation system also has **declinating points** (points de declinaison). A declinating point is one through which several **known lines** pass; that is, lines which are materialized on the ground and whose Y-azimuth is known.

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## APPENDIX 11.

## TOPOGRAPHICAL METHODS.

**464.** The preparation of fire and the organization of observation involve the following topographical operations:

(*a*) Determination of a line.
(*b*) Location of a point.
(*c*) Determination of the altitude of a point.

### DETERMINATION OF A LINE.

**465. Using a declinated instrument.**—This is described in connection with the use of such instruments (par. 126, et seq.).

**466. Using an undeclinated instrument** (such as the observation telescope, aiming circle, or theodolite).

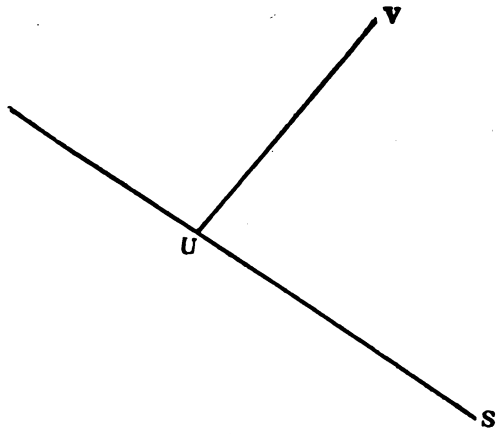


FIG. 68.



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Paragraphs 127 and Appendix 12 describe the orientation of an instrument at an orienting point.

When an orienting point is not available, any known line US (par. 127) may be used, by setting up over any point U of this line and orienting the instrument by means of the known Y-azimuth of the line (fig. 68).

Any unknown line UV may then be determined.

This process is continued until the desired line is reached and determined.

This process is called an **angle traverse** (cheminement d'angles), and gives good results under the following conditions:

The courses, staked out in advance, should be as few and as long as possible, never less than 100 meters.

The instrument should be set up over the line in all cases to within 2 or 3 centimeters.

The error should then be less than:

5 mils, for a traverse of 2 or 3 courses with the plane table.

5 mils for one of 3 or 4 courses with the aiming circle or observation telescope.

2 mils for one of 5 courses with the Jobin theodolite.

With a given instrument, the error in determining a line increases with the number of courses. Above a certain number of courses, the error of the determination is greater than that with a declinated instrument. In such a case the latter method should be used.[1]

**467. Determination of a line by two known points.**—When a declinating point (par. 463) is not available for declinating the instrument or for beginning an angle traverse, two known points may be used. The line between these points is determined graphically or by calculation. The points used should be accurately known and sufficiently separated.

It is preferable to use points of the triangulation system; otherwise distinct points on the battle map, such as a steeple, an isolated building or tree, a road crossing, or exceptionally the corner of a wood.

If the determination is to be used in the preparation of fire, the distance between the points should be comparable to the ranges

[1] For the plane table or aiming circle, the number of courses should not exceed 2; for the theodolite, 4.

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involved, and to the distances of observation if an observation post is involved.

**468. Graphically.**—To determine a line graphically, plot the two points accurately with the double decimeter (not with the zinc square or window of the protractor), join the plotted points, and measure the Y-azimuth with the most accurate protractor available.

**By calculation.**—If $x$, $y$ and $x'$, $y'$ are the coordinates of the two known points, and $v$ the angle between the line joining the points and the X-axis of the map,

$$\tan v = \frac{x'-x}{y'-y}$$

$v$ is determined by means of tables of logarithmic or natural trigonometric functions. The Y-azimuth of the line for the point occupied is most easily found by inspection, $v$ being modified by an appropriate number of quadrants (par. 116).

**469. By astronomical observations.**—The determination of a line by astronomical observations requires a theodolite. The methods are described in **The Artillery Reconnaissance Officer.**

### LOCATION OF A POINT WITH A DECLINATED PLANE TABLE.

**470.** The plane table may be covered with a squared sheet of drawing paper, in which case the points used in the work are from the triangulation system or the battle map, plotted by their coordinates. Or a battle map may be mounted on the plane table and the known points on the map itself used.

To locate an unknown point on the plane table, the following methods are available:

- Intersection, Three-point Resection } Requiring sights for direction only.
- Direction and distance, Traversing } Requiring distance measurements also.

**471. Intersection** (intersection) consists in sighting on the unknown point X from at least two known points A, B, C, etc.

The plane table having been declinated, set it up at A (fig. 69) and orient it. Draw AX. Perform similar operations at B, C, etc.

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The lines AX, BX, etc., will in general not intersect in the same point. The center of the various intersections should be used.

The method is more accurate when the sights are short, and the intersections approximately at right angles. Intersections at acute angles (less than about 30°) should be avoided.

**472. Three-point.**—The location of an unknown point X by the three-point method consists in sighting on at least three known points A, B, C, etc., from X.

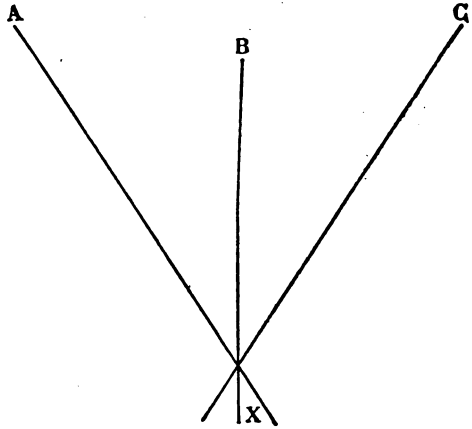


FIG. 69.

The declinated plane table is set up at X and oriented. Sight on the known points and draw the corresponding lines from the known points.

The common intersection of these lines is the point X. As with the method by intersection, short sights and nearly perpendicular intersections are desirable. If the three known points and the unknown point are nearly on the same circumference, the method should not be used.

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**473.** If the known points are distant (farther on paper than the actual length of the needle), or if the plane table is not accurately oriented, the method must be modified by including operations which will not only locate the unknown point, but also insure the orientation of the plane table. Such a procedure is called the **unoriented three-point method** (relèvement non orienté), and is described in **The Artillery Reconnaissance Officer.**

**474. Resection** (recoupement).—This method consists in locating an unknown point, which is on a known line, by sighting on at least two known points from the unknown point. The known line may be a sight from a known point, or a line shown on the map.

Set up the plane table over the unknown point X, orient it by the declinator, and sight on the known points A, B, etc., drawing the corresponding lines from the known points. The center of the intersections with the known line is the desired location.

**475. Direction and distance.**—This method consists in locating an unknown point X from a known point A, by determining the direction and distance of X from A.

The method may be used **directly** (rayonnement direct) or **inversely** (rayonnement inverse).

**Directly.**—Orient the plane table at A, sight on X, draw the corresponding line through A and lay off the distance AX from A.

**Inversely.**—Orient the plane table at X, sight on A, draw the corresponding line through A, and lay off the distance AX from A.

**476. Traversing.**—This method consists in determining a series of lines joined end to end by successive applications of the method of direction and distance, starting from a known point A. The determination of each of the lines constitutes a **course,** and the ends of the lines are the **points** of the traverse.

With a declinated plane table, only every other point of the traverse need be occupied. Let the points be numbered successively 1, 2, 3, etc.

Set up at A (fig. 70) and locate 1 directly by direction and distance. Then set up at 2, which is located inversely by direction and distance. From the same station locate 3 directly by the same method. Then set up at 4 and continue the same methods.

The traverse is made to pass through the unknown point X, but should continue past it to another known point $F_1$. The discrepancy between the location $F_1$ by the traverse and the true position

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F is called the **error of closure** and gives an idea of the accuracy of the traverse.

If the error of closure is not excessive, it may be distributed among the various points in proportion to their distances from the origin A. The point $X_1$ will be relocated at X so that

$$\frac{XX_1}{FF_1}=\frac{AX}{AF}.$$

If the error of closure is excessive, the traverse should be repeated in the opposite direction.

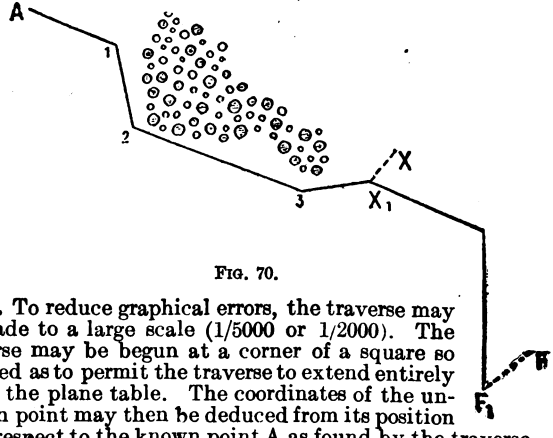


FIG. 70.

**477.** To reduce graphical errors, the traverse may be made to a large scale (1/5000 or 1/2000). The traverse may be begun at a corner of a square so selected as to permit the traverse to extend entirely across the plane table. The coordinates of the unknown point may then be deduced from its position with respect to the known point A as found by the traverse.

**478.** A traverse should be as direct or rectilinear as possible.

If, for example, the point 6 (fig. 71) can be seen from the initial known point A, 6 should be used as a station and a sight taken on it from A. The intermediate stations 1, 2, 3, etc., will then be needed only in connection with stadia measurements of distance and slope if necessary. The plane table need not, in this case, be carefully set up since it serves only to support the telescope alidade-



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This effects a saving of time and increases the accuracy.

The point 6 is plotted by its direction as established from A and by the total distance as determined from the traverse.

**479. Traversing by back sight and fore sight.**—When the plane table is not declinated, or is imperfectly declinated, or when ocal attraction is feared, all of the stations of the traverse must be occupied. The plane table is oriented at the known point by sighting on other known points. The first station is then located by direc-

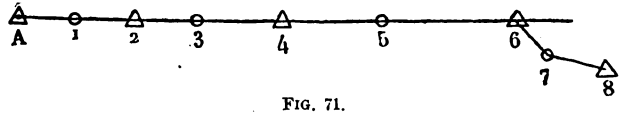


FIG. 71.

tion and distance. Orientation at the second station is by a back sight on the initial station. The third station is located by direction and distance from the second. The process is continued in this manner.

The plane table must be set up carefully, with the station on the map accurately over the stake on the ground. Short courses must be avoided.

### LOCATION OF A POINT WITH A DECLINATED THEODOLITE OR AIMING CIRCLE.

**480.** The declinated theodolite or aiming circle may be used for the operations previously described (pars. 470 to 479) for the plane table.

The observations and measurements are recorded, and the results are determined afterwards graphically or by calculation.

**481. Operations on the ground.**—At each station the instrument is oriented by the declinator. The reading for direction is then the Y-azimuth.

The observations, azimuths, distances, and slopes if needed are recorded, preferably in diagrammatic form.

**482. Graphical solution of the work.**—This work is generally done on a drawing board, with the protractor and the rule or double decimeter. The constructions incident to the methods of intersection, three-point, resection, direction and distance, and traversing

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are entirely similar to those made on the ground when the plane table is used.

**Calculation.** Calculation of the results is not ordinarily employed for work with a declinated instrument. The methods are described in **The Artillery Reconnaissance Officer.**

**483.** When the Y-declination is not known, the same methods may be used, but it is necessary, either during the work or afterwards, to sight on a known line. A comparison of the reading of the known line and its Y-azimuth will give a constant by which the directions recorded during the work may be converted into Y-azimuths.

### LOCATION OF A POINT WITH AN UNDECLINATED GONIOMETER.

(Observation telescope theodolite without a declinator, or aiming circle or compass theodolite in a region subject to magnetic disturbances.)

**484.** The operations in this case, like those of paragraphs 480, et seq., consist of measurements on the ground, which are afterwards resolved either graphically or by calculation.

**485. Intersection** (par. 471).—Set up at a known point A with the 0 of the instrument in any direction. Sight on the unknown point X, using the upper motion, and also on two or three known points as distant as possible. Note the readings for these sights. A comparison of these readings with the Y-azimuths of the known lines read will give a constant by which the Y-azimuth of the line AX may be deduced and plotted from A.

A similar operation is effected at the other known points B, C, etc.

**486. Three-point** (par. 472).—Set up at the unknown point X and sight on four or more known points, using the upper motion. Note the readings. The points selected should be as close as possible.

Lay off these readings from a point on a separate piece of tracing paper. Place this on the map or other plot of the known points and move it about until the lines representing the sights taken all pass through the known points visible through the tracing paper. Prick through the point on the tracing paper. This is the location of the unknown point.

This method is the simplest solution of the three-point problem, and also the least accurate. Other methods are explained in **The Artillery Reconnaissance Officer.**

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**487. Resection** (par. 474).—Set up at a known point A and read the unknown point X, as well as two or three known points as distant as possible, using the upper motion.

Then set up at X, and in the same manner read A and two or three known points as close as possible.

Plot the line AX in the same manner as for intersection (par. 485). Determine the Y-azimuth of AX from the readings at A. The Y-azimuths of the readings of the known points taken at X can then be determined from the Y-azimuth of AX. The sights from X on the known points can then be plotted from the latter points by means of their Y-azimuths.

**488. Direction and distance** (par. 475).—The direction of the unknown point X is determined and plotted from a known point A in the same manner as for intersection (par. 485). The distance AX is measured directly and laid off from A.

**489. Traversing** (pars. 476 to 479).—The method by fore sight and back sight is used, it being necessary to occupy all of the stations.

Set up at a known point A and sight in succession on two or three known points as distant as possible and also on the first station 1, using the upper motion. Increase the reading on 1 by 200 grades, or 3,200 mils.

Set up at 1. Set off this reading on the instrument and, using the general motion, back sight on A. The 0 of the instrument is then in the same direction as at A. Then sight on the second station 2. Increase the reading by a semicircle as before and proceed to the next station. The process is thus continued.

In constructing the traverse, the Y-azimuths of the known lines read at A afford a means of deducing a constant by which all readings for direction can be converted to Y-azimuths, since the 0 of the instrument had the same Y-azimuth throughout the operations. A large scale of, say, 1/2000 should preferably be used.

**490.** When a theodolite is used in connection with known points of the triangulation system in applying these methods, the observations are best resolved by calculation. The methods are described in **The Artillery Reconnaissance Officer.**

### DETERMINATION OF THE ALTITUDE OF A POINT.

**491.** The altitude of a point can usually be read directly from the map by means of the contours. If there is no contoured map, or if there is reason to question the accuracy of the contours available, a

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leveling operation is necessary, based on a point of known altitude. The methods used may be:

Measurement at the point of unknown altitude X of the angular elevation of known points A, B, etc.

Measurement at known points of the angular elevation of the unknown point.

Traverse from a known point, with measurement of slopes, closing on another known point.

When haste is necessary, by barometer.

Whatever method is used, the points involved should be as close together as possible.

**492.** Known points may be bench marks or any other map details whose altitude is accurately shown on the map. The altitude of points along a water course can be arrived at sufficiently accurately from bench marks along the banks at intervals as great as several kilometers.

**493. Leveling by measuring the slope.**—The difference in level between two points can be found from their angular difference in level and the horizontal distance between them.

Let H be the altitude of the ground at the point occupied.

H′ the altitude of the ground at the point sighted upon.

$h$ the height of instrument at the point occupied.

$h'$ the height above the ground of the point sighted upon.

$i$ the angular difference in level.

D the horizontal distance between the two points.

The points should not be more than 4 kilometers apart, on account of refraction. When the point of known altitude is occupied, the unknown altitude may be found from

$$H'=H+D \tan i+(h-h')$$

When the point of unknown altitude is occupied,

$$H=H'-D \tan i-(h-h').$$

**494. Calculation of D tan i.**—With the telescope alidada, the slide rule of the alidade may be used. Direct calculation with natural or logarithmic tangents may also be used.

When $i$ is not too large, $i$ may be substituted for its tangent.

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When $i$ is in mils and D in kilometers,

$$D \tan i = D\, i, \text{ or, more accurately, } .982 \times D \times i.$$

When $i$ is in grades and D in kilometers,

$$D \tan i = 15.7 \times D \times i.$$

When $i$ is in degrees and D in kilometers,

$$D \tan i = 17.4 \times D \times i.$$

**495. Leveling by barometer.**—If $h - h_0$ is the difference in barometric pressure at two points, the difference in level between the two points in meters is

$$Z = k \times (h - h_0)$$

where $k$ is a coefficient which varies with the mean barometer and the mean temperature of the two points.

The following table gives the values of $k$ for the various values of the mean temperature $\frac{(t+t_0)}{2}$ and mean barometer $\frac{(h+h_0)}{2}$;

VALUE OF K.

| Mean barometer. | Mean temperature—C. | | | | |
|---|---|---|---|---|---|
| | −10° | 0° | 10° | 20° | 30° |
| 780 | 9.87 | 10.24 | 10.62 | 10.99 | 11.37 |
| 770 | 10.00 | 10.38 | 10.76 | 11.14 | 11.52 |
| 760 | 10.13 | 10.52 | 10.90 | 11.29 | 11.67 |
| 750 | 10.26 | 10.66 | 11.04 | 11.44 | 11.83 |
| 740 | 10.40 | 10.80 | 11.19 | 11.59 | 11.99 |
| 730 | 10.54 | 10.95 | 11.35 | 11.75 | 12.16 |
| 720 | 10.69 | 11.10 | 11.51 | 11.91 | 12.33 |
| 710 | 10.84 | 11.25 | 11.67 | 12.08 | 12.50 |
| 700 | 11.00 | 11.41 | 11.84 | 12.25 | 12.67 |
| 690 | 11.16 | 11.58 | 12.01 | 12.43 | 12.85 |
| 680 | 11.32 | 11.75 | 12.18 | 12.61 | 13.04 |
| 670 | 11.49 | 11.93 | 12.36 | 12.80 | 13.24 |
| 660 | 11.67 | 12.11 | 12.55 | 13.00 | 13.44 |

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## APPENDIX 12.

## INSTRUMENTS.

**496. Firing board** (planchette de tir).—This is a drawing board of wood or wood and zinc, covered with squared paper.

The orienting line, base piece, base points, objectives, datum points, witness points, observation posts, etc., are plotted on it.

It is used for the constructions and measurements incident to the preparation of fire.

A battle map may be used instead of the squared paper.

**497. Protractors** (rapporteur).—Protractors are semicircular in zinc or celluloid. They are used for measuring or laying off angles. The graduations are in mils, decigrades, or R-mils. The accuracy of a protractor increases with its size.

In **measuring a firing angle** (or base angle), when the protractor is graduated in the same direction as the deflection scale of the sight, the 0 of the protractor is placed on the desired line of fire (base line). The reading is made at the line of sight (orienting line). If the angle is greater than a half circle, a half circle must be added to the reading of the protractor.

When the protractor and sight are graduated in opposite directions, the 0 of the protractor is placed on the line of sight (orienting line), and the reading made at the line of fire (base line), increased if necessary by a half circle.

In **measuring the Y-azimuth of a line,** when the protractor is graduated clockwise, the 0 of the protractor is placed on the Y-line, and the reading made at the line whose Y-azimuth is desired. The reading is increased by a half circle if necessary.

If the protractor is graduated counterclockwise, the 0 is placed on the line whose Y-azimuth is desired, and the reading made on the Y-line. The reading is increased by a half circle if necessary.

**498. To draw a line of given Y-azimuth through a point A.**—Draw a Y-line through A by means of measured offsets from the nearest Y-line equal to the offset of A. Deduct a half circle from Y-azimuth if it is greater than a half circle.



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If the protractor is graduated clockwise, place its 0 at the Y-line, and mark the position of the desired line at the proper graduation.

If the protractor is graduated counterclockwise, place the given reading at the Y-line, and mark the desired line at the 0.

**499. Parallax protractor.**—This is a protractor of large radius, covering only a small angle. The radii of the graduations are drawn full length. They are also graduated in distance from the center.

The celluloid form is 85 cm. long. Its distance graduation is to the scale of 1/20000.

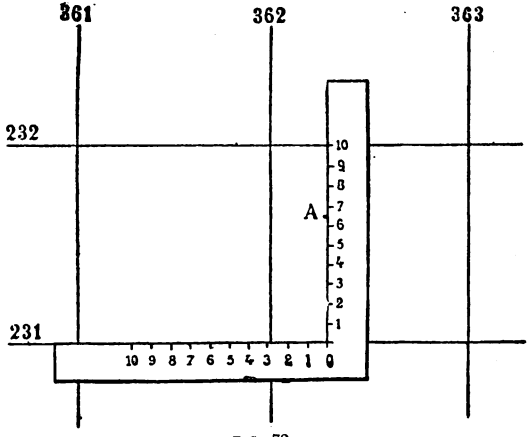


FIG. 72.

The tracing paper form is used to measure small angles on a large scale map, when the center is off the map. The map must have a radius on it and a point whose length of radius is known. The protractor need be only partially unrolled, so as to expose the portion corresponding to the known length of radius.

The white paper form is 4 meters long and is used to draw angular graduations on a map, when the center is off the map. The map is laid on the protractor, and a straight edge reaching across the map is used to connect the uncovered portions of the radii of the protractor.

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**500. Map square** (équerre en zinc).—This square is of zinc, and is graduated to 1/20000. It is used to measure the coordinates of a point on the battle map, or plot a point of given coordinates.

**501. To measure the coordinates of a point** (par. 459).—To measure the coordinates of A (fig. 72), apply the square with the horizontal graduated edge along the X-line and extending to the left of A, and the vertical graduated edge passing through A. Read the fractions of a kilometer which must be added to the kilometric coordinates.

**502. To plot a point of given coordinates.**—Let the given coordinates be:

$$x=362.280$$
$$y=231.650.$$

Apply the square as before, with the horizontal graduated edge along the X-line for which Y=231. Slide the square along this line until the graduation 280 is at the Y-line for which X=362. Mark the required point at the graduation 650 of the vertical graduated edge.

**503.** The zinc decigrade protractor has a window which is the same as a map square.

**To plot a point accurately,** the double decimeter scale should be used, and not the map square or protractor window.

**504. Straight edge** (règle à dessin). **Scale** (règle graduée). **Double decimeter** (double décimètre).—These are used to draw straight lines and measure distances. The straight edge of the protractor may be used if it is true.

### PLANE TABLE—TELESCOPE ALIDADE—SLOPE RULE ALIDADE.

**505.** The plane table is a device for performing topographical operations by direct graphical constructions.

The plane table is covered with squared paper or a battle map. The use of the plane table involves either:

The telescope alidade and stadia rod, or

The slope rule alidade and steel wire (or decameter tape).

**506. To set up and level the plane table.**—In setting up the plane table, it should be placed so that point occupied is directly under the corresponding point on the plane table.

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In leveling with the slope rule alidade, the alidade should be placed parallel to two legs of the tripod. These two legs are then seated so as to center the bubble of the alidade. The alidade is then placed perpendicular to its first position, and the third leg moved so as again to center the bubble. These operations are repeated until the bubble is centered for all positions of the alidade. The tripod legs should be clamped before the final verification of the operation. They should be unclamped before the tripod is closed for transport.

With the telescope alidade, the operations are the same except that but one position of the alidade is necessary, since the level is a spherical one.

If the plane table is not level, the angles constructed are not horizontal ones, and the declinator needle will not oscillate freely.

**507. To orient the plane table** (par. 117).—Set up the plane table over a known point A, from which several other known points B, C, etc., can be seen. Let *a*, *b*, *c*, etc., be the corresponding plotted positions of these points. Set the alidade on the line, say *ab*, loosen the plane table, turn it so that the alidade is sighted on B, and reclamp it. Verify this orientation by similarly placing the alidade on the lines *ac*, *ad*, etc., and sighting on the points C, D, etc.

If, due to slight errors in the plotted positions of the points, the sights do not give accurate coincidence on all of the points, the plane table should be moved slightly so as to reduce the discrepancies as much as possible.

**508. To declinate the plane table.**—Having oriented the plane table, set the declinator so that the blue point of the needle is exactly opposite its index. Clamp the declinator and mark its position by a light pencil line around the outside.

Verify this operation, by reorienting the plane table by means of the declinator, and sighting on the known points used for the first orientation. This is essential to check the sensitiveness of the needle and insure that it is oscillating freely.

**509.** The declination of a plane table varies with the particular instrument used; in other words, the **declinator can not be changed** without redeclinating the plane table. **Always use the same edge of the alidade.**

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The declination is accurate only in a particular locality. If the locality is changed, the declination must be made anew.

**510.** If the points of the needle are sharp, both ends may be used. Coincidence at both ends is secured if possible; if not, the points should be separated from their indices by the same amount.

**511. To determine a given line with the declinated plane table.**—Orient the plane table over any point of the line to be determined. With the alidade, sight on the most distant visible point of the line. Draw a line the full length of the rule. Prolong the line by sliding the alidade along the part already drawn and sighting again on the line. **Never use the slide rule of the telescope alidade in drawing a sight.**

**512. To construct a line passing through a known point A.**—It is desired to determine the line AX, A being a point plotted on the plane table and X an unknown point.

Orient the plane table at A or X. Sight on the other point, by moving the alidade in the desired direction but keeping the edge accurately on the plotted position of the known point A. Draw the line.

**513. To measure a distance.** (*a*) **With the telescope alidade.**—Hold the 2-meter stadia rod vertically at the point whose distance from the station is sought. Bring the right vertical scale of the reticule on the stadia rod.

Set the graduation on the lower mark of the rod and read the graduation of the telescope scale at the upper mark of the stadia rod.

If the slope is small, the distance thus read may be taken as the horizontal distance; if it is considerable, the distance read must be reduced to the horizontal.

When the stadia rod is not all visible when held vertically, it may be held horizontally and perpendicular to the line of sight.[1] The horizontal scale of the reticule is then used.

When the distance is less than 25 meters, use the stadia rod 1 meter long,[2] and divide the distance read by 2.

**514.** (*b*) **With the 20-meter tape.**—Two men are necessary. The forward man carries a bundle of iron or wooden stakes, and is

[1] This condition is difficult to obtain, and the horizontal rod should not be used, unless the vertical position is not entirely visible even with the rod raised off the ground.

[2] With the folding stadia rod, a 1-meter base can be had between one mark and the bolt which unites the two halves of the rod.

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lined by the rear man. Each length is marked by a stake. The rear man pulls up the stake as he leaves it in going on. This gives a means of counting the lengths.

In moving forward, the tape is held taut and not allowed to drag.

If more accuracy is desired, the measurement can be repeated in the opposite direction. The discrepancy should not be more than 1/1000 of the distance. When this second measurement is not considered necessary, gross errors should be avoided by pacing the distance. This will at least insure detection of an error in counting the number of lengths.

**515. To measure a slope.** (*a*) **With the slope rule alidade.**—Center the bubble by means of the cams. If the slope is ascending, use the lower peep and the right edge of the slit; if descending, the upper peep and the left edge of the slit. The graduations are 10 mil, but mils can be read by interpolation.

The middle peep can be used with the same scales, but the slope read should be decreased 200 mils.

**516.** (*b*) **With the telescope alidade.**—Bring the point measured on the grade scale of the reticule. Center the bubble by means of its screw.

Read to 5 grades on the external scale, and the grades and centigrades on the reticule. The total reading, **less 100 grades,** is the slope with its sign.

In measuring a slope, the point read should be at the height of the instrument.

### AIMING CIRCLE (GONIOMÈTRE-BOUSSOLE), MODEL 1916, MODEL 1917.

**517. Description.**—The aiming circle is an instrument used for the preparation of fire. There are two models in mils, which differ only in a few details. They are designated as the Model 1916 and the Model 1917.

The **telescope** is a small prismatic one of 4-power, and a large field of view. The Model 1917 has a focussing eyepiece O. The telescope and declinator are mounted on the upper motion Q.

The telescope has a movement in a vertical plane (when the instrument is level), which is essentially parallel to the index line of the needle. It can be leveled independently of the rest of the instrument by means of a level V fixed to it. It is actuated by a worm U.

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The reticule has a vertical line for sighting in direction, and a sight graduation from —100 mils to +100 mils. The axis is at the intersection of the vertical line and the 0 of the sight scale.

In the Model 1916 there is a dotted graduation to the right of the vertical line giving the normal height of burst of 3 mils (par. 240). In the Model 1917 there is a stadia scale in meters for use with a 2-meter stadia rod.

**518.** The **declinator** has a needle release D, by means of which the needle can be raised from the pivot for transport. For transport, the lever should be to the right.

There is a small prism for magnifying the needle index. In the Model 1917 only the needle index is adjustable by means of a small screw near the prism support. This permits instruments to be accurately standardized.

**519.** The **general motion** is either rapid, by loosening the clamp C, or slow, by the worm S with C tightened.

The **upper motion,** carrying the telescope and declinator, is either slow, with the worm W engaged, by means of the milled head T; or rapid, by disengaging the worm W, which is eccentrically mounted.

If the worm does not engage under the action of its spring when released, do not force it, but turn the milled head T slightly, when it will drop into engagement.

**520.** The **tripod** consists of three telescoping legs and a sliding vertical support, which is clamped by the screw B.

The aiming circle is fixed to the tripod by a ball joint R, clamped by a screw G. It is leveled by a spherical level H, fixed to the general motion.

With the Model 1916, for accurate work, the vertical support of the tripod should not be extended. This is not necessary with the Model 1917, which can be fully extended, giving heights from 0 m. 80 to 1 m. 80.

**521.** The **graduations** are continuous from 0 to 6,400 mils. Hundreds of mils are read on the graduation on the general motion at the black index X. Units are read on the micrometer at the index Y.

In the Model 1916, this graduation has a double numbering, the red figures being for a clockwise graduation and the black figures for a counterclockwise graduation.

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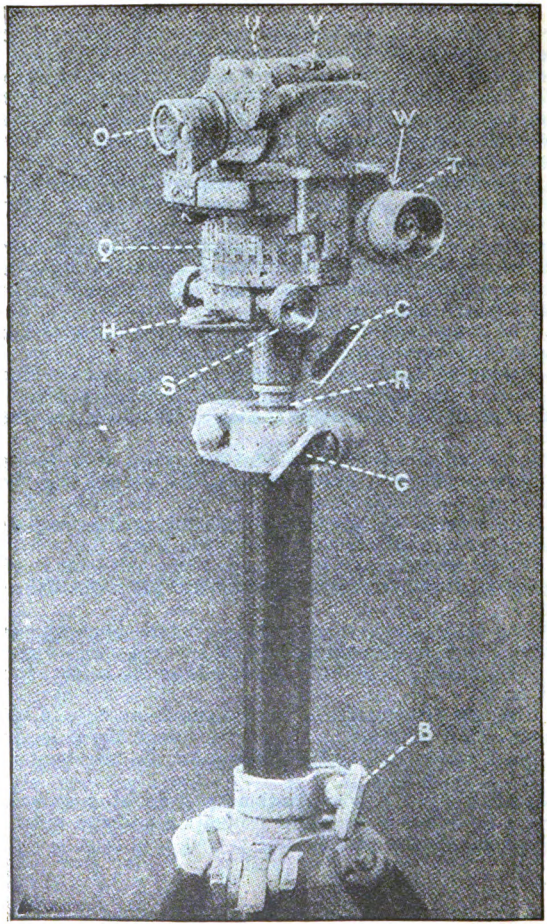




FIG. 73.

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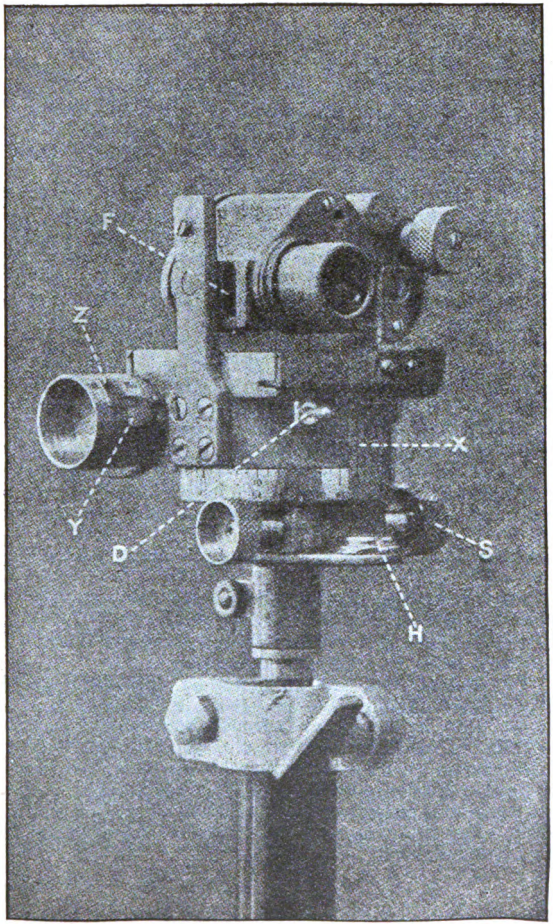


FIG. 74.



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In the Model 1917, there is only the red numbering, for a clockwise graduation.

Since the aiming circle is primarily intended for the 75 gun, a special scale is provided which permits an angle to be read directly in the units of the sight graduation (plateau and drum). This is used for reciprocal laying, as explained in paragraph 148. The 0 of the principal scale corresponds to plateau 0, drum 100 of the special scale.

One of the quadrants of the upper motion is divided into eight equal parts marked Pl. 0, Pl. 2..., Pl. 14. Four indices on the general motion are provided for this scale. They are triangular black marks at 0, 16, 32, and 48 of the general motion. The plateau is read on the special scale at whichever index is covered by the scale.

Each plateau division of the special scale is divided into two halves, one clear and the other crosshatched in red. If the plateau index is at a clear portion, the mils are read on the micrometer at Y, and will be between 0 and 100. If the plateau index is at a crosshatched portion of the special scale, the mils are read at the index Z (marked by red crosshatching), and will be between 100 and 200.

**522. A lighting device** for night observation is provided, consisting of a cell box and cell, a rheostat, a switch, connections, and a bulb. The lamp is attached to the left telescope support so as to throw light on the scale in the field of view through the window F. The lamp can also be used for lighting the scales and the declinator needle.

When this device is not available, an ordinary pocket flash light can be used.

**523. To set up the aiming circle.**—Set the tripod so that the axis is over the desired point on the ground, with the sliding support vertical. Loosen the clamp G, and level the instrument with the spherical level H. Tighten the clamp.

**524. To orient the instrument by sighting on known points.**—The orienting point used (par. 127) may be a declinating point (par. 463), or any point O from which several known points can be seen. If a declinating point of the triangulation system is used, the known lines for it are listed with their Y-azimuths.

If any other known point is used, the Y-azimuths of the known points seen from it must be determined by calculation or graphically (par. 468). Let these values be $\alpha$, $\beta$, $\gamma$, etc., for the lines OA, OB, OC, etc., respectively.

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Set up at O, with the instrument set at $\alpha$ on the continuous red graduation. Loosen the clamp C of the general motion and point the telescope roughly at A. Tighten C and sight accurately on A by means of the slow-motion worm S of the general motion.

Without disturbing the general motion, sight on the known points A, B, C, etc., and again on A. Note the readings for each. Let them be represented by $\alpha'$, $\beta'$, $\gamma'$, etc. If the readings are not at variance with the correct Y-azimuths by more than 1 mil, the instrument is oriented. If the discrepancies are more than 1 mil, take the mean of the differences $\alpha-\alpha'$, $\beta-\beta'$, $\gamma-\gamma'$, etc., designated as $\epsilon$.

Then move the general motion by $\epsilon$ in the appropriate direction, and repeat the readings on the known points as previously explained. Continue this process until the readings obtained are the correct Y-azimuths.

In making the sights on known points, the points should always be approached in the same direction.

**525. To declinate the aiming circle.**—The instrument is oriented as just explained. Then bring the needle index opposite the needle by means of the upper motion, being careful to secure accurate coincidence. Note the reading. Repeat this operation several times, and take the mean of the readings, which is the declination constant **for this particular instrument.** Record the value on the instrument.

If the instrument is used in another locality, it must be redeclinated.

The Y-declination given by the map can be used only as a rough approximation. As a matter of fact, the telescope is not necessarily accurately parallel to the needle when the latter is opposite its index. The discrepancy in this respect may be as great as 20 or 30 mils.[1]

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[1] But with the Model 1917, having an adjustable needle index, the instrument can be adjusted so that its declination constant will be any desired value, such as the Y-azimuth of the magnetic north, given on the battle map.

Let $a$ be the Y-declination (par. 463). Then the Y-azimuth of the magnetic north $V_m$ is

$$V_m = 6400 - a.$$

Orient the instrument accurately as described in paragraph 524. Then, without disturbing the orientation, set the instrument at $V_m$. Adjust the needle index to accurate coincidence with the needle.

Such an adjustment is of practical value only in standardizing two or more instruments.



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**526. To orient a declinated instrument.**—Set the instrument at its declination constant and, by means of the general motion, bring the needle accurately opposite its index.

**527. To determine the Y-azimuth of a line AB.**—Set up the instrument at any point A of the given line and orient it. Sight on B, using the upper motion. The reading on the continuous red graduation is the Y-azimuth of B from A.

**528. To measure an angle.**—The angle between two lines may be obtained by measuring and subtracting the Y-azimuths of the lines. If this angle is all that is required, it is unnecessary to orient the instrument. The following is sufficient.

Set up at O, and sight on the left point, using the general motion. Then point on the right point, using the upper motion. The reading of the continuous red scale is the angle between the two lines.

**529. To measure the sight.**—Point the instrument so that the objective is on the vertical scale of the reticule. Level the telescope. Read the site on the reticule, being careful of the sign.

**530. To measure a distance.**—With the **Model 1917** aiming circle and the 2-meter stadia rod, the operation is the same as with the telescope alidade (par. 513*a*).

With the Model 1916 instrument, read the vertical (preferably) angle L subtended by the stadia rod, by means of the mil-scale in the field of view. The distance D is given by the expression:

$$D=\frac{K}{L}$$

where K is a constant (about 2,000) previously determined.[1]

[1] To determine K, tape three distances on the ground of 25 m., 30 m., and 40 m., from the instrument. Measure the angles subtended by the stadia rod held vertically at these three distances. These values should be about 80, 67, and 50 mils, respectively. For each value, find the product D×L. Take K as the mean of the three products.

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## OBSERVATION TELESCOPE.

(Longue-vue monoculaire.)

**531.** The prismatic observation telescope is used for observation, principally at long range, and for the preparation of fire.

**Model 1917** (Type X. Campagne, Modèle 1917), for matériel having a sight graduated in 6,400 mils.

**Model 1916 R** (Type X. Campagne, Modèle 1916 R), for matériel having a sight graduated in R-mils (6,000 to the circle).

**Siege and position** (Type X. Siège et place), for matériel with the siege goniometer.

The other models are similar to one of these, differing only in small details.

**532. Features common to the three types.**—There are three eyepieces, mounted on a turret. The powers are 15, 23, and 30.

The 15-power is suitable for use on dark days, or at twilight or dawn. The illumination is superior to that of the higher powers.[1]

The 23-power is the normal one for use on a clear day. The illumination is somewhat greater than that of an 8-power field glass.

The 30-power is superior on a very clear day for long-range observation.

The telescope is mounted above a goniometer, which is fixed to a tripod. It has a movement in elevation, and a sitometer.

**533.** Both the general motion and the upper motion have slow and rapid movements, generally similar to those of the aiming circle (par. 519).

**534. Graduations. Model 1917.**—There is a clockwise graduation, 0 to 6,400 mils, similar to that of the aiming circle (par. 521).[2]

The site device is operated by the worm U. The graduation is in mils. The hundreds are read on the disk V, and the units on the micrometer Z. There are two sets of graduations, one in black for positive sites and one in red for negative sites.

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[1] The illumination is proportional to the square of the diameter of the emergent pencil of rays, which can be seen as a small circle of light when the eye is placed a short distance (6 or 8 inches) from the eyepiece. The diameter of the emergent pencil is the effective diameter of the objective of the telescope divided by the power.

[2] The Model 1917 is intended primarily for the 75 gun, and is provided with the special scale for reading plateau and drum (par. 521).

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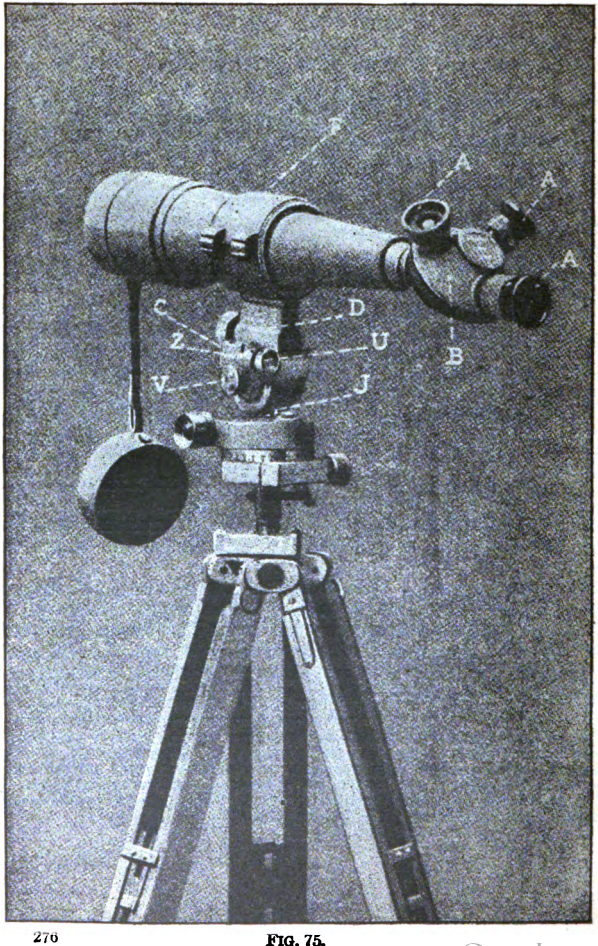




FIG. 75.

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## OBSERVATION TELESCOPE.

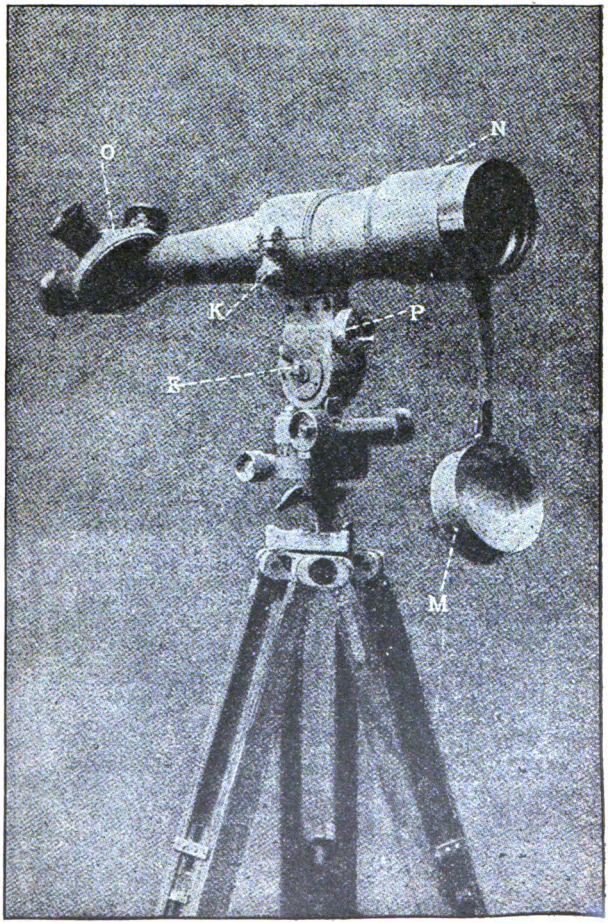


FIG. 76.



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TRIPOD AND GONIOMETER OF OBSERVATION TELESCOPE.

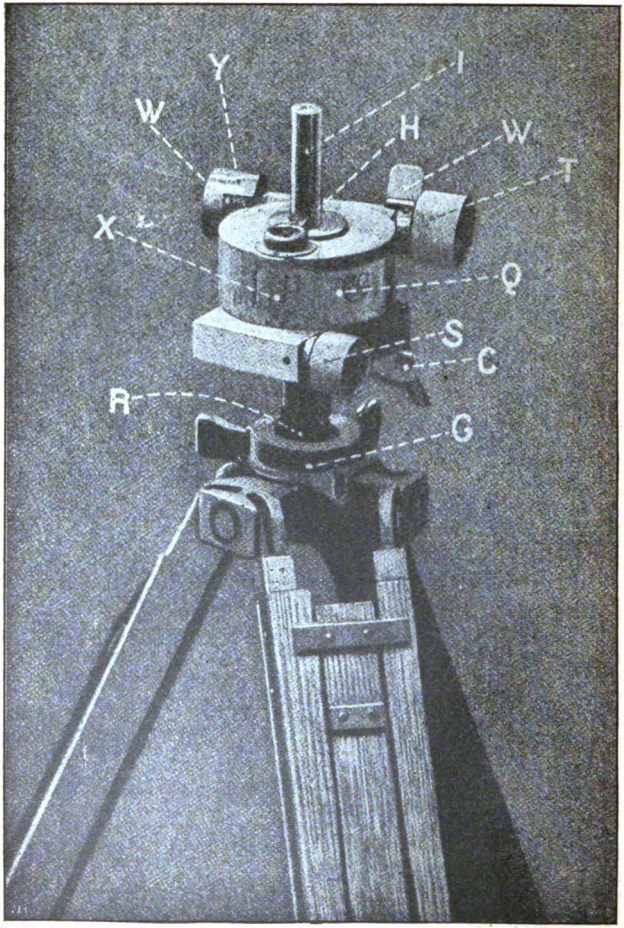




FIG. 77.

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The reticule has a cross in the center, marking the optical axis; and two scales, one horizontal and the other vertical, with 5-mil graduations. The normal height of burst, 3 mils (par. 240), is indicated between the cross and a special graduation.

**Model 1916 R.**—There is a single continuous graduation, from 0 to 6,000, and a double numbering in red and black. The former is clockwise and the latter counterclockwise. There is no special scale. The site device and the reticle are the same as for the Model 1917, except that they are graduated in R-mils.

**Siege and position.**—There is a continuous graduation in decigrades, from 0 to 4,000, with a double numbering: Red, clockwise; and black, counterclockwise.

The sitometer is graduated in degrees and minutes. The graduations are to 5 degrees on the disk and to 5 minutes on the micrometer. The graduations are numbered in black for positive sites and in red for negative sites.

The reticule has a horizontal scale in single decigrades and a vertical scale with 4-mil graduations.

**535. To set up the instrument.**—Remove the tripod and goniometer from the case, taking care to see that they are locked together by the clamp C.

Extend the tripod legs to the desired height and embed them firmly in the ground.

Level the goniometer by means of the ball and socket joint R and the spherical level H. The joint is locked by the winged nut G.

Remove the telescope mounting from its case, and place it on the pivot I of the goniometer, first loosening the clamp E, by pressing down the lever. Engage the stud J in its recess. Tighten the clamp E.

Place the telescope on its mounting and secure it.

**536. To use the telescope.**—Use the eyepiece, which is in prolongation of the axis of the telescope. Focus the eyepiece. Its graduation is in diopters.[1]

[1] A diopter is a unit used in expressing the refractive power of lens. A person who requires a concave spectacle lens of 1 diopter for seeing distant objects would, in focusing a telescope, set the eyepiece at −1. Similarly, for a convex lens the setting would be +.

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The power may be changed by revolving the turret B, carrying the three eyepieces. The turret is secured in its three positions by a spring catch. The catch releases upon the application of pressure to turn the turret and reengages when the turret is in a position for use.

In dismounting the telescope, the 15-power eyepiece should be set for use. The clamp C should be securely locked.

**537. To measure the angle between two points.**—If both points are simultaneously visible through the telescope, the reticule may be used.

Otherwise set the instrument at 0 and sight on the left point by means of the general motion. Then sight on the right point, using the upper motion.

The reading on the continuous red graduation is the angle desired.

If the graduation is numbered both in black and red, the first sight may be on the right point. In this case the final reading on the black scale is the angle desired.

**538. To measure the site.**—Set the instrument on the objective, using the vertical motion and the crosshairs of the reticule. Level the sitometer by means of the worm actuating it. Read the site (par. 532).

**539. Use in observation of fire.**—Set the instrument at 0 on the adjusting point, using the general motion.

The deviation of the burst, and its height if desired, can ordinarily be measured on the reticule. When the burst is out of the field of view, it can sometimes be picked up by rapidly moving the instrument with the upper motion. In this case the reading would be on the external scale. The setting should be verified when the instrument is returned to the adjusting point.

**540. Use for general observation.**—When used in an observation post, the instrument should be set at 0 on a specified origin line (par. 94), or oriented, according to the orders received. The observations are reported by the reading on the continuous red scale, the instrument being pointed by means of the upper motion. The orientation should be verified from time to time.

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## SCISSORS TELESCOPE.

(Longue-vue binoculaire.)

**541.** The scissors telescope is a binocular prismatic instrument for the reconnaissance of objectives and the observation of fire. It consists of two telescopes mounted on a common pivot so as to be capable of rotation in a lateral vertical plane.

The arms may be disposed horizontally for stereoscopic vision, or vertically for periscopic vision. With the arms horizontal, the distance between the objective lenses is about 10 times as great as that between the eyepieces. The objects viewed are thus brought quite strongly into relief unless they are too distant.

There are three principal types of the instrument:

Model 1917, in mils.
Model 1916 R, in R-mils.
Siege and position, in decigrades, for matériel using the siege goniometer.

**542. Features common to these three types.**—The power is 12. The illumination is somewhat greater than the service 8-power field glass, and permits observation in poor light, as at dusk or daybreak, or on dark days.

The right eyepiece has a reticule, which can be rotated by a milled collar on the outside so as to be in the proper position for any position of the arms.

The instrument can be moved in elevation and has a sitometer. It is mounted on a goniometer, which is in turn mounted on a tripod.

**543.** The goniometer, sitometer, and the reticule are of the same type and with the same graduations as the corresponding types of observation telescopes (pars. 532 to 541).

**544.** In the older models, the goniometer has no micrometer. The types A, B, BC, D, and E are graduated in mils.

The types DD, F, G, H, and I have two graduations, one in mils and the other in decigrades. The sitometer is in mils. The reticule has an upper horizontal scale in decigrades, a lower horizontal scale in mils, and a vertical scale in mils.

**545. To set up the scissors telescope.**—This operation is similar to that for the observation telescope (par. 535). The telescope and its mounting are united.

Each eyepiece is focused separately.

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SCISSORS TELESCOPE, STEREOSCOPIC VISION.




FIG. 78.

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## SCISSORS TELESCOPE, TYPE D, PERISCOPIC VISION.

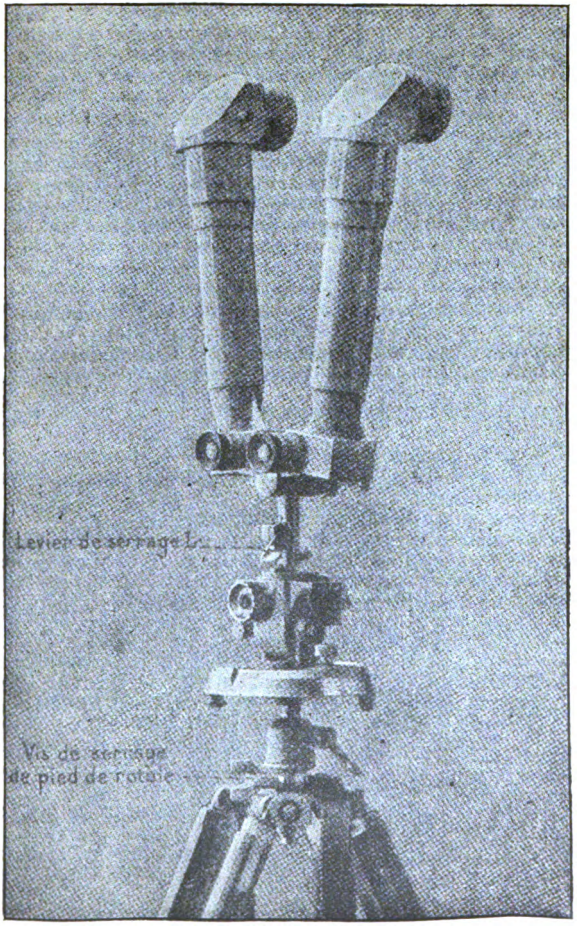


FIG. 79.



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After the eyepieces are focused, the arms are set by loosening the clamp of their pivot and moving the arms by hand until the two fields of view are accurately superposed, the arms being horizontal or vertical as desired. The pivot clamp is then locked. When properly adjusted in this manner, the object viewed will be seen with the maximum brilliancy. The pivot is graduated in millimeters, so that when the arms have been set for an individual observer, he can note the setting for future use.

**546. To dismount the telescope.**—The arms are unclamped and folded down on the mounting to the left. The pivot is left unclamped. Place the telescope and its mounting in the case with the objective lenses on the side of the cover hinge.

In putting the tripod in its case, see that the clamp C is firmly locked.

**547.** The operations of measuring sites and angles and observing are similar to those with the observation telescope (pars. 537–540).

### FIELD GLASSES.

**548.** Field glasses are used for general observation or for the adjustment of fire. They have reticules for the measurement of small angles.

The type most widely used is 8-power.

The higher powers, such as 10, 12, and 16, can be used successfully only exceptionally, because the field of view is small, the illumination poor, and it is difficult to hold them steady. A support can be used to overcome this latter difficulty.

### SIGHTING CIRCLE.

**549.** The sighting circle is an observing instrument so arranged as to permit the measurement of horizontal angles.

It consists of a semicircular wooden table, with a pivot at the center. The table carries a zinc protractor in mils or decigrades, and has a level.

The pivot will receive:

(*a*) A special slope rule alidade, with an index for reading angles on the protractor.

(*b*) A special slope rule alidade, with a luminous wire, for use at night.

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## SIGHTING CIRCLE.

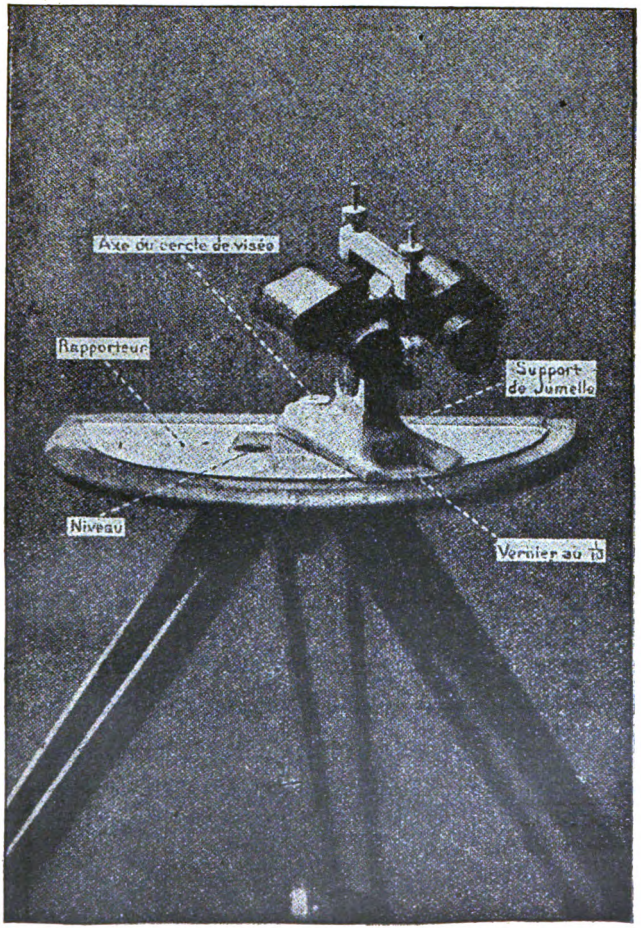


FIG. 80.



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(*c*) A special alidade for night use, which is electrically lighted.
(*d*) A field glass support for the service glass, with an index for reading angles on the protractor.

The sighting circle may be solidly mounted on a wooden frame or on masonry in an observation post. It can also be mounted on a plane table tripod.

### SITOGONIOMETER, MODEL 1911.

**550.** The sitogoniometer, intended primarily for the light artillery, is a pocket instrument for rapid approximate measurements during

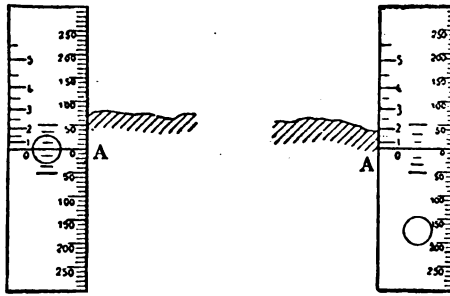


FIG. 81.

a reconnaissance, or at any time when more accurate instruments are not available.

It is used for:

(*a*) Measuring the site and determining the minimum range which will clear the mask.

(*b*) Measuring angles in mils and transforming them into terms of plateau and drum.

Consequently, it is sufficient for the rapid preparation of fire in indirect laying.

The instrument is contained in an aluminum case. On one face there is a table of parallaxes. A handle is provided, which also serves as a point of attachment for a cord.

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**551. To measure the site and find the minimum range.**—(*a*) **Site.**—Hold the instrument, edge to the front, at the height of the eye, in such a manner as to see the site bubble and also external objects on the right side. Incline the instrument to the front or

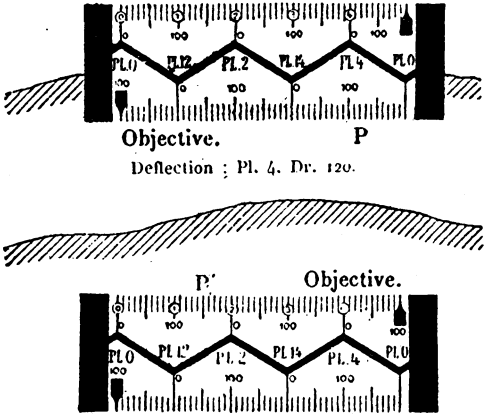


FIG. 82.

rear so as to center the bubble. Read the graduation seen at the height of the objective.

(*b*) **Minimum range.**—At the gun position, again hold the instrument as if to measure a site. Select a point A on the mask of the same site as the objective. Move the instrument so this point is seen to the left. Bring the 0 of the scale to the height of the point selected, and read the minimum range at the summit of the mask, 1,800, as in (fig. 81).[1]

[1] This can only be used for distances from the mask not greater than 300 meters and with the normal charge.

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**To measure angles and deflections.**—Hold the instrument horizontally, edge to the front, close to the right eye so as to see the deflection scales [1] and at the same time distant objects over or under the instrument.

Bring one or the other of the indices at Pl. 0 [2] on the objective, the lower one if the aiming point is on the right of the objective, and the upper one if the aiming point is on the left of the objective. The deflection is then read at the aiming point in terms of plateau and drum.

If an angle is to be measured, look over the upper edge and use the encircled figures with the 0 on the left.

### CARE OF INSTRUMENTS.

**552.** The following should be observed in the care of instruments:

(*a*) Keep in as dry a place as possible.

(*b*) When an instrument comes in wet, wipe it off carefully before putting it away.

(*c*) Do not subject an instrument to shock. Do not use force with it.

(*d*) Cleaning should be limited to the exterior. In cleaning a lens do not use cloth or other matériel which can grease or scratch. Breathe on the surface and wipe it lightly with a piece of fine dry linen. Repeat this process until the moist surface has a smooth dull appearance and evaporates regularly and concentrically.

(*e*) In handling theodolites do not touch the scales with the fingers. When wet, remove the moisture with a piece of clean, dry, fine linen, lightly oiled, **without rubbing.** Remove dust without rubbing.

(*f*) It is strictly forbidden to clean, adjust, or dismount the interior of instrument, unless specifically authorized by regulations. Instruments out of order should be sent in for repair.

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[1] The total length of the scale is exactly 533 mils, 1/3 of a quadrant.

[2] These indices are so marked as to make them easily recognizable.

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# PART V.

# METHODS OF FIRE.

## APPENDIX 13.

### SIGHT ADJUSTMENT—CALIBRATION.

**553. Sight adjustment.**—The laying instruments of the base piece are usually taken as **reference instruments** (instruments de référence).

The object of the sight adjustment is to compare the instruments of the other pieces with the reference instruments.

**554. Quadrant.**—Lay the piece in question successively at the elevations 0° 30′, 1° 30′ . . . , n° 30′. For each position of the piece, measure accurately the elevation $a$ with the reference quadrant, and the elevation $a'$ with the quadrant of the piece used.

The differences $a'—a$ can then be used to form a table of corrections to be applied to the various elevations used by the base piece to eliminate differences due to the quadrants (par. 196).

If the piece is calibrated, these corrections are included in the calibration corrections (par. 556).

**555. Sight.**—Lay the piece for direction successively at the following deflections:

| 75. | | Mils. | Grades. |
|---|---|---|---|
| Pl. | Dr. | | |
| 0 | 100 | 50 | 50 |
| 2 | 100 | 150 | 150 |
| 4 | 100 | 250 | 250 |
| ..... | ..... | ..... | ..... |
| 14 | 100 | 6,350 | 3,950 |



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For each position of the piece, measure accurately the deflection $b$ with the reference sight and the deflection $b'$ with the sight of the piece used.

The differences $b'-b$ can then be used to form a table of corrections to be applied to the various deflections announced to the base piece (par. 191), in order to eliminate differences due to the sights.

**556. Calibration.**—The object of calibration is to determine the individual elevation corrections to be applied to pieces other than the base piece, so as to obtain uniform results in range (par. 196).

Calibration in practice does not entirely achieve this object, but nevertheless is decidedly advantageous.

The calibration correction (correction de régimage) varies with the range [1] and from time to time. It should be determined about every 1,500 or 2,000 rounds for the small calibers; about every 1,000 rounds for the medium calibers. It should also be determined for as many ranges as possible, at least at 3,000 and 6,000 meters for the small calibers and 5,000 and 10,000 for the large calibers.

Select a clearly visible and accurately known point near the middle of the field of fire and at a suitable range.[2]

Fire for improvement on this point with at least 12 rounds per piece. Current precision fire should be utilized as far as practicable for this purpose.

Four adjusted elevations are thus obtained for the same objective, $a_1$ (reference piece), $a_2$, $a_3$, and $a_4$. The calibration corrections for the pieces other than the reference piece are then:

$$c_2=a_2-a_1$$
$$c_3=a_3-a_1$$
$$c_4=a_4-a_1$$

These and similar results for other ranges are the means of preparing a table of corrections for each piece other than the reference piece. The chief of section applies these corrections to the announced elevation.

---

[1] It may be taken that the calibration correction is applicable, whatever the powder lot used, for ranges within 3/4 or 4/3 of the range for which the determination was made.

[2] The point should be located by intersection from at least 3 terrestrial *observation posts*.

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## APPENDIX 14.

## STRIPPING AN ADJUSTMENT.

### DEFINITION OF THE COEFFICIENT $K_c$.

**557.** The object of stripping an adjustment (par. **281**) is to obtain information which will facilitate to the greatest possible extent subsequent firing with the same powder lot.

Stripping is based on the following considerations:

Let A be the map range of an objective, which for this discussion is accurately plotted on the battle map.

At the instant of firing, a certain number of disturbing influences act to alter the normal trajectory of the firing tables, so that the ballistic range (distance ballistique) D is different than the map range A. The ballistic range is obtained by fire for adjustment.

The difference $D-A=M$ is the total correction to be applied to the map range to offset the disturbing influences.

Among the influences measured by M are some which are known and can be evaluated. Let $M'$ be the correction for these known influences. It is evident then that if the fire be opened, not with the map range A, but with the range $D'=A+M'$; that is, with the map range corrected, as far as practicable, the initial range will be less erroneous and the adjustment simplified.

This is in general the method actually used.

**558.** The adjustment gives the ballistic range.

$$D=A+M.$$

From both sides of this equation substract the corrections $M'$ for known influences. Then

$$D-M'=A+M-M'.$$

$D-M'$ is called the stripped range. The equation may also be written

$$\frac{D-M'}{A}=1+\frac{M-M'}{A}=K_c.$$



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$M-M'$, from discussion, represents the incompleteness of the evaluation of the disturbing influences for the range A. Its value is unknown, but from our general knowledge of the nature of such influences it is evident that it increases with the range.

**559.** Experience shows that the difference $M-M'$ is proportional to A, on condition that—

The same powder lot is used.

The ranges considered do not differ too much from A, or more specifically, if they are within 3/4 to 4/3 of A (par. 564).

Therefore the ratio $\frac{M-M'}{A}$ is constant, which makes $K_o$ constant also, under the conditions stated.

**560.** Stripping an elevation or range consists practically then in finding coefficient $K_o$ for the powder lot used. This is done by stripping the ballistic range D of the corrections $M'$ for the known influences, and dividing this range $D-M'$ by the map range A.

**561.** Having found $K_o$, the ballistic range $D_1$, for a new objective whose map range is $A_1$, can readily be found.

If $M'_1$ is the correction for the known influences affecting the fire on the new objective, by the value previously stated for $K_o$

$$\frac{D_1-M'_1}{A_1}=K_o$$

that is, $D_1=K_oA_1+M_1$.

Thus the map range $A_1$ is modified by multiplying it by $K_o$, and correcting this **modified range** for the known disturbing influences $M'_1$. This gives the **corrected range** (par. 192).

**562.** Because the value of $K_o$ is only approximate, the corrected range will not in general be found exact. It is, however, much more accurate than if $K_o$ were not used, which justifies the use of the method.

### MEANING OF $K_o$.

**563.** Thus far $K_o$ has been considered as an abstract quantity, without physical significance. The various influences entering into it have not been dwelt upon.

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These are:

Site of the objective.
Wind.
Air density.
Weight of projectile.
Quickness of the powder lot.
Powder temperature.
Wear of the piece.

Certain of these influences can be accurately evaluated, such as the site of the objective and the weight of projectile. Others can be evaluated only approximately, such as the wind and air density. Others can not be evaluated, such as the quickness of the powder lot and the wear of the piece.

$K_0$ covers the incompleteness of the evaluation of these influences (par. 558).

This incomplete evaluation consists of two parts:

Errors in evaluating the known influences.

Influences not known and not evaluated.

The first part is slight and negligible in comparison with the second. The term $M-M'$ in the value of $K_0$ consists, for practical purposes, of the second part. From paragraph 560 it is thus seen that $K_0$ depends on the powder lot and the piece used.[1]

**564.** The quickness of the powder lot and the wear of the piece have influences which may be measured by a variation in muzzle velocity. The value $M-M'$ may therefore be expressed by a range correction $m$ due to the velocity variation.

Then

$$K_0=1+\frac{M-M'}{A}=1+\frac{m}{A}.$$

Therefore the assumption that $K_0$ is constant holds only within such limits of map range that $m/A$ is sensibly constant.

These limits can be found by trial, using the firing tables. Assuming a map range A and a correction in this range of $m$, the corresponding variation in muzzle velocity can be calculated. Using the

[1] Calibration firing corrects for difference between individual pieces. Reference here is to the failure of the reference piece to conform to the firing tables, due to irregularities in the piece itself.

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same variation in muzzle velocity, the range correction $m_1$ can be found for a different map range $A_1$.

By continuing this process, it will be found that the ratio $m/A$, and consequently $K_o$, is constant only for values of $A_1$ between 3/4 and 4/3 of A (par. 292).

### METHOD OF USING THE VELOCITY CORRECTION, $V-V_o$.

**565.** The restrictions on the use of the coefficient $K_0$ can be avoided. Referring again to the equations of paragraph 558, let

$D'=A+M'$ be the corrected range (par. 192) for the first firing, only the known influences being corrected for, and

$D=A+M$ be the range corresponding to the adjusted elevation.

Then $D-D'=M-M'=m$ (par. 564).

The correction $m$ corresponds, for practical purposes, to the total variation of muzzle velocity due to the powder lot and the condition of the piece for the range A. The value of this variation in muzzle velocity, $V-V_0$, can be calculated from the firing tables.

**566.** If it is afterwards necessary to fire with the same powder and piece, at **any** other map range $A_1$, the range correction $m_1$ for the new range $A_1$ can be readily found from the firing tables, by means of $V-V_0$. $M'_1$ can be found for the known conditions of the moment as previously.

Then the corrected range for the new objective will be

$$D_1=A_1+M'_1+m_1.$$

Because it has no restriction as to the new map range with respect to the one previously used, the method by using the variation of the muzzle velocity is more general in its application than the method using $K_0$.

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## APPENDIX 15.

## CHART FOR TIME FIRE BEHIND CRESTS.

**567. Use.**—Calculate from the battle map the slope $n$ in per cent (par. 21) of the ground to be covered.

Find from the firing tables the angles of fall $\omega$ and the remaining velocity, $V_r$ for the range to be used.

For example, to cover a slope of 9%, when:

$$\omega = 25°$$
$$V_r = 300 \text{ m.}$$

Read on the line (1), opposite the slope in per cent, the slope in angular units, $\epsilon$ (5° opposite 9%).

Draw a line from the point, 9%, on (1) through the point on (2) $\omega - \epsilon$ (25° − 5°).

Join the point where this line intersects (3) with the point on (5) for the remaining velocity (300 m.).

At the point where the line last drawn cuts (4), read the nearest value of the ratio H/E. H is the range bound in meters and E the corresponding fuze bound in seconds. In the case

$$\frac{H}{E} = \frac{100}{.1}.$$

The ratio H/E means that to maintain the burst on a line parallel to the ground, the fuze setting should be increased [1] 0.1 second for each increase of range of 100 meters. These particular values need not necessarily be used, but the two values should be in this ratio. The range bound is based on the usual considerations (pars. 263 and 264).

To find the actual range bound on the ground, join the point for $\omega$ (25°) on the **red** graduation of (2) to the point previously found on (3), and prolong this line to intersect (4). Read on the **red** graduation of (4) the ratio B (1.25) of the range bound on the ground to that on the horizontal. A range bound of 100 meters thus corresponds to 125 meters on the ground.

[1] If the corrector is used, the fuze setting is increased by decreasing the corrector.



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## APPENDIX 16.

## ADJUSTMENT BY HIGH-AIR BURSTS.

**568. Object.**—By this method, objectives hidden from terrestrial observation may be attacked with zone fire (par. 259), without aerial observation. The objective must be accurately located on the battle map.

The method may be used by day or night. It is easier and more accurate at night.

Fire for effect may be percussion or time.

**569. Method.**—A series of high-air bursts, fired with the same data by the base piece of a battery, are accurately located by intersection from several observation posts. The charges in firing data necessary to bring the trajectory on the objective can be deduced from these observations.

**570.** Adjustment by this method is a function of the flash ranging groups.

The Artillery commander assigns the adjustments necessary to appropriate groups, and establishes the order of priority for each group.

Each group is furnished the coordinates of the base piece of each battery for which it may have to make adjustments. These should **not** be communicated by telephone.

Permanence of telephone communication is essential to the success of the method.

**571.** The operations by the battery and the flash ranging group are as follows:

The battery commander causes the base piece to be laid on the objective and forms the sheaf.

The officer in charge of the flash ranging has a **trajectory chart** (abaque de trajectoire) showing the trajectories for all elevations. He locates the objective on this chart by its range and altitude with respect to the base piece.

The fuze setting is determined from the chart so as to give bursts of sufficient height to be surely visible.



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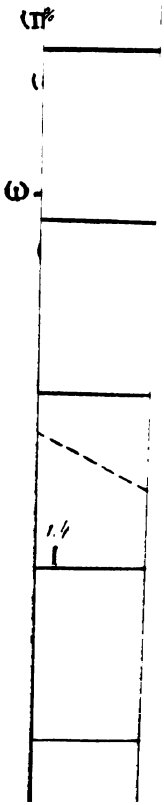
RESTS

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The elevation and fuze setting are transmitted to the battery commander, who corrects them for the conditions of the moment, and fires a series of 10 or 12 shots from the base piece, at the rate of one shot per minute.

The bursts are observed from three observation posts. One observer in each post measures the Y-azimuth of the bursts by means of the reticule of his instrument, which has previously been set in a known direction. A second observer in two of the posts measures instrumentally the site of the bursts.

The observations are sent to the central flash-ranging station, where the officer in charge, by simple graphical methods, locates the burst center horizontally and vertically with respect to the base piece. The burst center is then dotted on the trajectory chart and determines the trajectory through the burst center. The elevation change necessary to reach the objective can then be taken from the chart.

The deflection change necessary can be obtained from the horizontal position of the burst center with respect to that of the objective.

The necessary changes in elevation are transmitted to the battery commander, who makes suitable changes in the firing data, and passes to fire for effect (par. 257). This fire can be verified by observations similar to those previously made.

**572.** The method compares in accuracy to shifting fire (par. 287). Zone fire should be used in fire for effect. **Precision fire for effect** (par. 254) **should not be used in connection with this method.**

In general, the method is applicable in the following cases:

(*a*) Interdiction or harassing fire. This may be time or percussion fire and executed by day or night. The object may be to cover an area traversed by the enemy, or to prevent passage at essential points. The nature of these points is such that they will generally be well located on the battle map.

(*b*) Neutralizing fire, rapidly delivered on batteries already located, when aerial observation is not available. The accuracy of the method is sufficient to permit the use in fire for effect of two elevations differing by one fork.

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**573.** The method may be used in place of the datum point [1] when aerial observation is to be used for adjustment, and it is desired to place the first shots near the objective. The initial data in this case can be obtained directly from the battle map.

**574.** The method may be used in place of a witness point. After an adjustment has been accurately made by any method, high air bursts may be fired with the adjusted elevation. This will fix the adjusted trajectory. Subsequent fire can then be checked by again resorting to high air bursts and comparing the trajectory thus determined with the adjusted trajectory.

**575.** The method may be used for testing fire (par. 171), by day or night. It is particularly advantageous against captive balloons.

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[1] Often difficult to locate under the present conditions.

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## APPENDIX 17.

### SOUND RANGING (Réglage par le son).

**576.** Sound ranging should be used by heavy artillery in adjusting its fire, when conditions are suitable and when aerial or terrestrial observation is impracticable.[1]

Experience has shown that, under suitable conditions, this method gives results which compare favorably with those by the other methods.

**577. Objectives.**—Sound ranging is generally used in attacking hostile batteries previously located by the sound ranging group which is to conduct the adjustment. The adjustment is undertaken as soon as the battery is again found to be active.

If the adjustment is undertaken at once, after the battery is discovered for the first time, there is a certain delay between the location of the objective and the adjustment. The accuracy of the adjustment is less certain under these circumstances.

The use of sound ranging for adjusting on an objective known only by its coordinates is much less accurate than when the objective has been located by sound ranging, and should be resorted to only when atmospheric conditions are especially favorable.

**578.** Sound ranging requires the use of shells of large explosive capacity, and its application is therefore limited principally to calibers of **155 mm. and above.** The 120 may be used when conditions are very favorable.

The long shell is the most suitable, but the semisteel shell can also be used. Instantaneous or non-delay fuzes should be used.[2]

**579.** The fire must be carefully prepared, in order that large changes will not be necessary.

**580. Conditions for use.**—An excessive artillery activity, either friendly or hostile, can hamper the use of sound ranging or prevent it entirely.[3]

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[1] At night or on a dark day, or when the objective is hidden.

[2] IA fuzes are not used, for, although they are favorable for adjustment, their trajectory is altered when other fuzes are substituted in fire for effect.

[3] If conditions warrant, friendly artillery activity may be stopped, in order to permit an important sound ranging adjustment.



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Stability of atmospheric conditions is essential. An adjustment should not be undertaken if the wind velocity is over five meters, or if changes in atmospheric conditions during the adjustment are expected.

It is only by careful examination of the conditions of the moment that the advisability of undertaking an adjustment can be determined. **Decision on this point should be based on the advice of the sound ranging officer in charge,** who should also decide when the adjustment should begin.

**581. Telephone communication.**—Continuous and satisfactory telephone communication is essential throughout the adjustment.

**582. Preliminary arrangements.**—In the normal case of a hostile battery, previously located by sound ranging, the adjustment should be undertaken as soon as possible after the battery is again discovered in action. The adjustment should proceed as rapidly as possible.

This end can be attained only when the sound ranging groups and the batteries to fire are held constantly in readiness to undertake the adjustments contemplated.

**583. Programs of adjustments.**—The artillery commander of the sector accordingly draws up a program of adjustments.

The objectives for which sound ranging is to be used in adjustment are indicated. Batteries are assigned to fire on these objectives, which the sound ranging groups have ordinarily already located.

The objectives covered by the program are in two classes:

(*a*) Those to be attacked immediately upon call by the sound ranging group concerned.

(*b*) Those upon which fire can be opened only after first obtaining authority.

The program thus avoids delays due to consulting higher commanders when quick action is necessary.

The program is communicated to the sound ranging group.

**584.** The sound ranging group prepares charts for the adjustment beforehand. It gets in touch with the batteries with which it is to work, as shown by the program, and arranges for prompt and reliable telephone communication.

The artillery commander of the sector causes practice exercises to be held to assure the smooth operation of these arrangements.

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**585. Method of fire.**—In adjusting by sound ranging, the method by measured deviations is used.[1]

The adjustment is by piece.

The battery fires by successive salvos. The sound ranging group determines the range and deflection deviations for each piece and reports them to the battery. The changes are made for each piece, based on the center of the shots fired by each.

On account of the delay incident to the location of shots, the adjustment is carried only to a point which will enable the data suitable in fire for effect to be calculated. These data are then modified and verified during fire for effect without interrupting the fire.

**586. Fire for adjustment.**—The sound ranging group uses only one adjusting point in locating the shots, even when the fire is distributed.[2]

The sound ranging group notifies the battery when it is ready. The fire is delivered at a suitable rate, the sound ranging group being notified of the number of each piece as it is discharged.

When the record is imperfect, the sound ranging groups may call for additional rounds from a particular piece, or several pieces.

The deviations are reported to the battery, in **range** (meters) and in **deflection** (meters or angular units).

The salvos are usually fired at 10 seconds interval, and the interval between the salvos of a series is about 2 minutes.

**587.** The firing data having been carefully calculated for the conditions of the moment, the battery fires a series of 2 salvos.[3]

The sound ranging group reports the center of the two shots fired by each piece, with respect to the adjusting point.[4] The battery makes the necessary changes.

---

[1] The operations of the sound ranging group require a considerable time. The different series can not therefore be considered as having been fired under the *same conditions*, and the usual method (par. 228) is not applicable.

[2] When the fire is distributed, the battery should notify the sound ranging group, so that the latter will not be surprised at the size of the deflection deviations.

[3] If the objective has a narrow front, the sheaf may be converged for adjustment and opened in passing to fire for effect. If the pieces of the hostile battery are considerably separated, the fire should be distributed from the start so as to adjust each piece on its appropriate objective. To this end, the sound ranging group supplies a sketch showing the hostile battery as it has been located and also the adjusting point chosen.

[4] If the battery so requests, the sound ranging group reports the deviations for all shots. Abnormal shots are always reported.

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**588.** The battery then fires three salvos, which are reported as previously and the necessary changes made, based wholly on this series.

**589. Fire for effect.**—The data determined as a result of fire for adjustment are used in fire for effect at a single range.[1]

Three salvos are first fired in the way of verification at the usual rate,[2] followed at once by volleys for effect.

As soon as the results of the first three salvos are reported, any necessary changes are made and the fire continued.

In order to verify the fire from time to time, salvos are resumed and three fired at the usual rate for adjustment. The sound ranging group is given timely notice of this. The fuzes are changed if necessary.

If the successive variations show a regular change in the data, such changes can be predicted for the succeeding fire up to the next verification.[3]

**590. Use of the witness point.**—It may happen that during a protracted fire for effect, the conditions may become unfavorable for further use of sound ranging.

It is well therefore to adopt measures to retain the advantages of the adjustment as far as it has been carried. This can be done by firing on a witness point with terrestrial observation during the intervals when the sound ranging group is working out its observations. Or the method by high air bursts may be used (par. 574).

**591. Remarks.**—If the sound ranging group reports that its records are not satisfactory or that the shots are becoming irregular, the firing is discontinued.[4]

**592.** If during the firing a particular piece gives abnormal deviations, this piece ceases firing and the adjustment proceeds without it.

**593.** A comparison of the centers for the various pieces in a particular series affords a very accurate means of determining the calibration corrections (par. 556).

Conversely, an accurate knowledge of the calibration corrections will materially simplify the adjustment by sound ranging.

---

[1] It should be possible ordinarily to begin fire for effect about one hour after the hostile battery is reported in action by the sound ranging group.

[2] If fire for effect calls for delay fuzes, these are not used until after this series.

[3] In this manner the fire for effect will be more continuously efficient under the constantly varying conditions.

[4] The adjustment should likewise be given up if the wind increases to over 5 meters.

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## APPENDIX 18.

## PERCUSSION ADJUSTMENT BY FLASH RANGING GROUPS.

**594.** The flash ranging groups (S. R. O. T.—Sections de recherche de renseignements par observation terrestre) should be utilized by batteries for percussion fire for adjustment, whenever the battery dispositions do not afford sufficient accuracy and when aerial observation is impracticable.

**595. Objectives.**—Ordinarily the flash ranging groups are used for percussion precision adjustments on slightly defiladed objectives, such as:

(*a*) Hostile batteries located by intersection on flashes (flammes)[1] or smoke.

(*b*) Objectives which are not visible with terrestrial observation but whose location is accurately known. The organization of the flash ranging groups is such that the observers can set their instruments accurately[2] on a known point even though it is invisible.

**596.** The defilade of the objective can not be too great, or else the effect of the burst will not be sufficiently visible for accurate intersection. The permissible defilade depends on the size of the burst; that is, on the kind and caliber of the ammunition used.

**597.** The method is very accurate when the flash ranging group has actually seen the objective,[3] or can see a known point whose position with respect to the objective is accurately known.

**The flash ranging groups should not be called on for adjustments on objectives which are visible from the battery**

---

[1] The flash ranging groups can not make accurate adjustments on objectives located by the glare of their flashes (lueurs).

[2] This is generally not possible for the observation posts of the batteries, because of a lack of a sufficiently precise organization. However, if there is a visible point near the objective whose position with respect to the objective is accurately known (by aerial photograph or otherwise), the adjustment may be made on this point by the usual joint observation (observation conjuguée). The flash ranging group need not be called upon in this case.

[3] The measurements of the observers are simply deviations with respect to lines which are known to pass through the objective. All topographic errors are thus eliminated.



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**observation posts, except under very exceptional circumstances.**[1]

**598. Firing battery.**—The method can be used by all calibers Calibers of 120 and under should use long shells. Instantaneous or nondelay fuzes are used ordinarily. The long fuzes are used only when they must be used in fire for effect.

The preparation of fire must be executed with great care in order to abbreviate the adjustment.

**599. Conditions governing the use of the method.**—An adjustment should not be undertaken unless the conditions for observation are satisfactory.

General Artillery activity does not necessarily constitute a serious hindrance, unless the firing of other batteries on the same or a nearby objective causes confusion of observations.[2]

The wind can lessen the precision of the adjustment when the defilade is sufficient to hide all but the smoke of the burst. The larger the burst, the less accurate are the intersections.

The method can be used at night, but the objective can be only slightly defiladed, and instantaneous fuzes must be used. If the objective is considerably defiladed, the firing must at first be on some point near the objective on which observation is easy,[3] and whose position with respect to the objective is accurately known.

Since the success of an adjustment depends largely on the conditions under which it is undertaken, it should be begun only on the advice of the officer charged with the flash ranging. This officer notifies the battery when conditions are favorable.

**600. Telephone communication.**—Uninterrupted telephone communication between the battery and the flash ranging group is indispensable for a prompt and satisfactory adjustment.

**601. Preliminary arrangements. Program of adjustments.**—The batteries and the corresponding flash ranging groups must be in constant readiness to undertake without delay any task that may be assigned to them.

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[1] Unless for practice.

[2] In such a case the Artillery commander may interrupt or divert the fire of certain batteries; if not, the adjustment must be given up.

[3] The same method may be necessary in the day time if observation is difficult in the immediate vicinity of the objective.

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For this reason, the Artillery commander in each sector draws up a program of adjustments involving the use of the flash ranging groups. The latter are consulted in the preparation of this program.

This program distributes the objective to be attacked among the various batteries.[1] It also designates the batteries to be called by the flash groups in case objectives are located in various parts of the sector.[2]

**602.** This program is communicated to the flash ranging groups, together with the coordinates of the batteries to fire.[3] The flash ranging groups make the necessoary preparations, and get in touch with the batteries with which they are to work.[4] Careful arrangements must be made to insure satisfactory telephone communication. There should be complete understanding as to the adjusting point, the kind of ammunition to be used, and the rate of fire.

Practice adjustments should be made frequently with either simulated or actual firing.

**603. The method.**—The method is by measured deviations (par. 228). The adjustment is by piece. The method of fire is by series of battery salvos.

The flash ranging group determines the center for each piece for each series of shots. The changes indicated are made individually for each piece.

Rapidity of adjustment is essential for accuracy in order to avoid changes in the atmospheric conditions.

The observation of the shots, their transmission to the central station, and the necessary graphical constructions consume a considerable amount of time. It is therefore essential that the adjustment be limited to the number of rounds absolutely necessary in order to undertake fire for effect. This fire may be checked at intervals by the flash ranging group.

---

[1] The flash ranging group prepares a list of objectives which it is prepared to adjust on. This list is used in preparing the program.

[2] Among these are the so-called wandering pieces (pièces nomades) the use of which is becoming very frequent, and which can rarely be successfully attacked other than by this method.

[3] The coordinates of a firing battery should never be communicated by telephone. In case of necessity only the Y-azimuth of the line of fire should be given, or else the coordinates of any point on this line.

[4] The program furnished the flash ranging group should give the habitual designation of the firing battery and the telephone central to which it is connected.



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In this way the adjustment of a battery of four pieces should not require more than a half hour.

**604. The adjustment.**—The flash ranging group uses only a single adjusting point,[1] with respect to which it measures all deviations.

The battery communicates the time of flight to the flash ranging group.

The flash ranging group notifies the battery when it is ready to observe. The battery fires at the rate previously agreed upon. The departure of each shot and the piece firing it are announced in succession.[2] When all of the shots of a series are not observed from three posts, additional shots are called for.

**605.** The deviations are announced to the battery in **deflection** and **range.** The former is in meters or angular units, as desired by the battery. The latter is in meters.

**606.** The rate of fire depends on the conditions of observation. This is the subject of agreement between the flash ranging group and the battery. The rate agreed upon must not be exceeded, especially in salvos. Accurate intersections on shots are impossible if they are too close together. **A regular rate of fire greatly facilitates observation.**

Under favorable conditions, a rate as great as two or three shots per minute can be used, both for a salvo and between the salvos of a series.

**607.** The sheaf having been formed (either converged or distributed),[3] the battery fires a series of two salvos with suitable data and at the proper rate.

---

[1] The adjusting point is chosen so that the shots of all pieces will be in the field of view of the instrument when it is pointed on this point. The individual deviations can then be measured by means of the reticule and errors due to backlash in the instrument avoided. The adjusting point need not be visible. It may be, for example, a hostile piece whose flash has been seen.

If the points on which the various pieces are adjusted are so widely separated as to require the use of separate adjusting points, the pieces should be adjusted individually.

[2] The departure of each shot must be accurately announced.

[3] In adjusting on a hostile battery, on a narrow front, the fire should be converged and distributed in fire for effect if necessary.

If the objective requires a wide distribution, the fire is distributed from the beginning of the adjustment. In this case, the flash ranging group supplies a sketch of the objective, as located, with the adjusting point indicated.

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The flash ranging group determines the center for each piece and reports to the battery the deflection and range deviations of each with respect to the adjusting point.[1]

**608.** The battery then fires six salvos with altered data. The flash ranging group reports the deviations of the centers as previously.

The data are accordingly modified and fire for effect is undertaken.

If the first salvo of a series is lost, the series is begun anew at a **different elevation.** If one or several shots of a piece are lost, the fire of this piece is completed at the end of the series.

**609. Fire for effect.**—Fire for effect is by volleys at a single elevation, using the adjusted data. It should immediately follow the adjustment. It should be delivered rapidly, with no attempt to preserve a regular rate of fire.

From time to time the battery asks the flash ranging group to verify the fire for effect. For this purpose salvos are resumed at the usual rate (the fuse being changed to that suitable for adjustment if necessary) and a series of six salvos fired. The deviations are reported, the firing data changed by the amount of these deviations, and fire for effect resumed at once.

**610.** In the cases where the adjustment is on a point near the objective (par. 599), the verification of the fire for effect must be on this same point. As such fire is without effect on the objective, it should not be resorted to oftener than is absolutely necessary. In such cases the verification can be made with one piece and the others changed accordingly.

If the successive verifications show a regular change, the necessary modifications of data may be predicted and applied progressively between verifications.

**611. Adjustment of a single piece.**—The adjustment of a single piece should be undertaken only in the case of large calibers or rapid fire matériel for the attack of a **small** objective.

A flash ranging group should not be called on for such an adjustment in the case of medium caliber slow fire matériel as the small effect does not justify the time consumed.

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[1] If the parts of the objecti e are so widely separated as to be considered as distinct objectives, select an adjusting point for each piece and adjust each separately.

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**612.** As the fire is by single rounds, all shots can be observed both during adjustment and fire for effect. The elevation can thus be continuously adjusted without interrupting the fire for effect.

The adjustment is by series of shots, the flash ranging group determining the center of each series.

**613.** The piece first fires a series of two shots, the center of which is reported. With modified data a second series of two shots is fired.

The data are again modified based on the second series and the fire continued by series of six shots. The modifications of data following each of these series are as follows:

First series: Reported deviations.

Second series: One-half of the reported deviations.

Third series: One-third of the reported deviations.[1]

**614.** When the change in data thus determined is less than one tabular range probable error and 2 mils in deflection, fire for effect may be begun without continuous observation by the flash ranging group.

If this result is not obtained with the fourth series of six shots discontinue the adjustment.

This method presupposes that the fire is **conducted rapidly and that the atmospheric conditions are stable.**

If the fire is prolonged, it is verified from time to time as requested by the battery. The verification is by series of six successive shots.

**615. Use of a witness point.**—If an adjustment by flash ranging is not followed immediately by fire for effect the battery should, on its own account, execute an adjustment on a witness point, real or fictitious (par. 293).

This is particularly important in active sectors where the flash ranging groups are continuously occupied.

**616. Adjustment on a fictitious (fictif) datum point.**—The usual method of adjusting on a datum point (par. 287) includes the selection of a clearly defined point on the battle map and the execution of a complete adjustment (trial and improvement fire).

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[1] The total changes made to include this series is the same as if the piece had fired a single series of 18 shots. The method by series has the advantage, however, that the shots are earlier brought close to the objective with an increased likelihood of producing some effect.

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The center of a series of shots fired with the same data, when accurately located by the flash ranging group by coordinates, constitutes both the datum point and the adjustment on it.

**617.** The method of using the flash ranging group in establishing such a fictitious datum point is as follows:

One piece fires 12 shots at any suitable elevation, at the rate agreed upon.

The flash ranging group finds the center and reports it to the battery by its coordinates. These coordinates are those of the datum point and the elevation used is the adjusted elevation (par. 219). The elevation must be taken generally so as to place the shots where they can be properly observed and also in the vicinity of objectives in connection with which the datum point is to be used.

**618.** On active fronts it is essential that the flash ranging groups devote their time to their principal missions, adjustments and the location of objectives. Under these conditions their use in observing fire on such datum points is exceptional.

On the other hand, during inactive periods, they should be used for this purpose as often as possible. Practice is thus afforded and ammunition is economized.

**619.** The remarks (par. 591 et seq.) in the case of sound ranging are applicable in the case of flash ranging.

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## LIST OF FRENCH AND ENGLISH TERMS.

| | |
|---|---|
| Abaque de trajectoire | Trajectory chart. |
| A berceau traîneau | With cradle and sled. |
| A l'essai | Under test. |
| A l'étude | Being studied. |
| A glissement | Sliding mount. |
| Affût à échantignolles | Mounted on wooden platform. |
| Alidade nivelatrice | Slope rule alidade. |
| Amorçage | Fuze (in general). |
| Amorçage de culot | Base-fuzed. |
| Amorçage instantané | Instantaneous fuze. |
| Amorçage de tête | Point-fuzed. |
| Amorce | Primer. |
| Angle au niveau | Quadrant angle of elevation or elevation. |
| Angle au niveau initial | Initial quadrant elevation. |
| Angle du but | Elevation for the objective. |
| Angle de chute | Angle of impact (in some firing tables translated as angle of fall). |
| Angle d'arrivée | Angle of fall. |
| Angle de direction | Firing angle. |
| Angle de départ | Angle of departure. |
| Angle d'essai | Trial elevation. |
| Angle de hausse | Elevation. |
| Angle d'incidence | Angle of incidence. |
| Angle d'observation | Observer displacement. |
| Angle de projection | Quadrant angle of departure. |
| Angle de réglage | Adjusted elevation. |
| Angle de relèvement | Jump. |
| Angle de surveillance | Base angle. |
| Angle de transport | Deflection change. |
| Annexe<br>Appendice | Appendix, or supplement. |
| Artillerie de renforcement | Reinforcement artillery. |



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| | |
|---|---|
| Artillerie de sûreté | Emergency artillery. |
| Artillerie de tranchée | Trench artillery. |
| Barrage | Barrage. |
| Barrage fixe | Fixed barrage. |
| Barrage semi-fixe | Semi-fixed barrage. |
| Barrage roulant | Creeping barrage. |
| Barrage (Lever le) | Lift the barrage. |
| Béton | Concrete. |
| Béton armé | Reinforced concrete. |
| Bombe | Bomb (of trench mortars). |
| Bouclier de gaine | Detonator protector. |
| Branche ascendante | Ascending branch |
| Branche descendante | Descending branch. |
| Bulletin de tir | Firing record. |
| But auxiliaire | Datum point. |
| But témoin | Witness point. |
| Cadence de tir | Rate of fire. |
| Camouflet | Camouflet. |
| Canevas d'ensemble | Triangulation system. |
| Canevas de tir, section de—d'armée. | Army topographical battalion (no exact equivalent in our service). |
| Canon court | Howitzer. |
| Canon long | Gun. |
| Canon de référence | Witness piece, reference piece. |
| Carnet de batterie | B. C. data book. |
| Carnet d'observations | Observation sheet. |
| Carnet d'observatoire | Observation post data book (O. P. data book). |
| Carnet de pièce | Section data book. |
| Cartouche spéciale | Special booster cartridge. |
| Causes perturbatrices | Disturbing influences. |
| Cercle de visée | Sighting circle. |
| Changement des conditions du tir. | Change in the firing conditions. |
| Chapeau | Cap sill (of dugouts). |
| Char d'assaut (artillerie d'assaut ou spéciale). | Tank. |

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|---|---|
| Champ de l'observateur | Field of the observer. |
| Charge d'emploi | Standard charge. |
| Cheminement d'angles | Angle traverse. |
| Claie | Screen. |
| Cloison | Lands (of the bore). |
| Coefficient de pente | Slope coefficient. |
| Coefficient balistique | Ballistic coefficient. |
| Coefficient de réglage | Adjustment coefficient. |
| Collimateur | Collimator. |
| Conditions du tir | Firing conditions. |
| Conduite du réglage | Conduct of the adjustment. |
| Consigne | Standing or special orders. |
| Contre-pente | Reverse slope. |
| Contradiction | Bracketing elevation. |
| Convergence des méridiens | Convergence of the meridians. |
| Correcteur normal | Normal corrector. |
| Correction de régimage | Calibration correction. |
| Correction de répartition | Distribution correction. |
| Correction de station | Station correction. |
| Correction complémentaire de site. | Complementary site correction. |
| Correction totale de site | Total site correction. |
| Correction complémentaire d'angle de site. | Complementary site correction. |
| Côtes de cheminement | Course (in traversing). |
| Courbe de sécurité | Curve of security. |
| Coup au but | Target shot. |
| Coup de flambage | Drying shot. |
| Croquis panoramique<br>Croquis perspectif | Panoramic sketch. |
| Croquis planimétrique | Place sketch. |
| Culot tronconique | Tapered base. |
| Déclinaison | Declination. |
| Défilement aux lueurs | Flash defilade. |
| Défilement aux vues aériennes | Aerial defilade. |
| Défilement aux vues terrestres | Terrestrial defilade. |
| Degré | Degree. |
| Dépouillement | Stripping an adjustment. |

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|---|---|
| Dépouillé | Stripped. |
| Dérivation | Drift. |
| Dérive | Deflection. |
| Dérive normale | Deflection constant. |
| Dérive provisoire | Uncorrected deflection. |
| Dérive de surveillance | Base deflection. |
| Détonateur | Detonating booster. |
| Dioptrie | Diopter. |
| Direction initiale | Initial deflection. |
| Direction origine | Origin or origin line. |
| Direction repère | Orienting line. |
| Direction de surveillance | Base line. |
| Distance d'éclatement | Burst range. |
| Distance balistique | Ballistic range. |
| Distance corrigée | Corrected range. |
| Distance de tir | Range (of an objective). |
| Distance initiale | Initial range. |
| Distance rectifiée | Modified range. |
| Distance topographique | Map range. |
| Données topographiques | Map data. |
| Dossier de l'observatoire | Observation post record. |
| Dossier de tir | Firing record. |

| | |
|---|---|
| Écart angulaire | Angular distance. |
| Écart en portée | Range error. |
| Écart en direction | Deflection error. |
| Écart moyen en portée | Range mean error. |
| Écart probable sur le sol réel | Probable error on the ground. |
| Écart probable pratique | Field probable error. |
| Échelon | Unit. |
| Échelonnement | Deflection difference. |
| Échelonnement de répartition | Distribution difference. |
| Éléments aérologiques | Meterological data. |
| Éléments initiaux | Initial data. |
| En surveillance | On the base line. |
| Entonnoir déblayé | Clean crater. |
| Équerre en zinc | Map square. |
| Erreur de fermeture | Error of closure. |
| Escadron, chef d' | Battalion commander. |

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|---|---|
| Espace mort | Dead space. |
| Évent | Fuze setting. |
| Évent initial | Initial fuze setting. |
| Explosif tassé | Compressed explosive. |
| Faisceau | Sheaf. |
| Fauchage | Sweeping. |
| Feuille de calculs | Data sheet. |
| Fiche de renseignements | Information card. |
| Flèche | Maximum ordinate. |
| Fourchette | Fork. |
| Fourchette latérale | Lateral fork. |
| Fusée | Fuze (proper). |
| Fusée à double effet | Combination fuze. |
| Fusée fusante | Time fuze. |
| Fusée percutante | Percussion fuze. |
| Fusée détonateur | Detonating fuze. |
| Gaine | Booster casing. |
| Gaine relais | Booster. |
| Gaz toxique | Lethal gas. |
| Gaz lacrymogène | Persistent or lachrymatory (tear) gas. |
| Gaz dégagé par l'explosion | Shell gas. |
| Gerbe | Shrapnel cone. |
| Gerbe de culot | Base sheaf. |
| Gerbe latérale | Lateral sheaf. |
| Gerbe d'ogive | Ogive sheaf. |
| Gisement | Y-azimuth. |
| Glacis | Forward slope. |
| Goniomètre | Angle-measuring instrument; also sight. |
| Goniomètre boussole | Aiming circle. |
| Goniomètre de siège | Siege goniometer. |
| Grade | Grade (angular unit). |
| Grossissement | Power (of a telescope). |
| Groupe | Battalion. |
| Groupement | Group. |

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|---|---|
| Hausse | Range setting. |
| Hauteur d'éclatement | Height of burst. |
| Hauteur d'éclatement en mètres. | Linear height of burst. |
| Hauteur-type | Normal height of burst. |
| Inclinaison | Inclination. |
| Inclinaison des tourillons | Inclination of the trunnions. |
| Indice | Index. |
| Instrument directeur | Director. |
| Instrument goniométrique | Goniometer. |
| Instrument de référence | Reference instruments. |
| Intersection | Intersection. |
| Intervalle d' éclatement | Burst interval. |
| Jalonné | Staked out. |
| Jumelles | Field glasses. |
| Latitude | Latitude. |
| Lieutenant orienteur | Reconnaissance officer. |
| Ligne de projection | Line of departure. |
| Ligne d'observation | Observing line. |
| Ligne de site | Line of site. |
| Ligne de tir | Line of elevation. |
| Longitude | Longitude. |
| Longue-vue binoculaire | Scissors telescope. |
| Longue-vue monoculaire | Observation telescope. |
| Lotissement | Sorting (of projectiles). |
| Marron à lueurs | Flash cartridge. |
| Masse couvrante | Covering mass. |
| Masque | Mask. |
| Mécanisme / Méthode | Method. |
| Méridien | Meridian. |
| Micromètre | Micrometer, or reticule (of a telescope). |
| Millième | Mil (angular unit). |
| Millième R | R-mil. |
| Millième vrai | True mil. |

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Nivellement barométrique.....Leveling by barometer.
Nord géographique.....Geographic north.
Nord Lambert.....Lambert north or Y-line.
Nord magnétique.....Magnetic north.

Observation axiale.....Axial observation.
Observation combinée bilatérale.Bilateral observation using the index method.
Observation conjuguée.....Bilateral observation using a battle map.
Observation unilatérale.....Unilateral observation.
Observatoire.....Observation post (O. P.).
Observatoire de commandement.Command observation post (C. O. P.).
Observatoire de réglage.....Firing observation post (F. O. P.).
Observatoire de renseignements..Intelligence observation post (I. O. P.).
Obus à charge arrière.....Base charge shrapnel.
Obus à gaz asphyxiant.....Gas shells.
Obus en acier.....Steel shell.
Obus allongé.....Long shell (O. A.).
Obus à balles.....Shrapnel (O. B.).
Obus éclairant.....Star shell.
Obus en fonte.....Cast-iron shell (O. F.).
Obus en fonte aciérée.....Semi-steel shell (O. F. A.).
Obus à mitraille.....Case shot (O. M.).
Obus de rupture.....Armor-piercing shell (A. P.).
Obus de semi-rupture.....Semiarmor-piercing shell.
Obus traceur.....Tracer shell.
Officier orienteur.....Reconnaissance officer.
Origine de la trajectoire.....Origin of the trajectory.
Ouverture de la gerbe.....Angle of opening.

Papier quadrillé.....Squared paper.
Parallaxe.....Parallax.
Pente arrière.....Reverse slope.
Pièce directrice.....Base piece.
Pièce guide.....Base piece.
Pièce nomade.....Wandering piece.

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| | |
|---|---|
| Piquet repères | Stakes. |
| Plan méridien | Meridian plane. |
| Plan de défilement | Plane of defilade. |
| Plan directeur | Battle map. |
| Plan d'objectif | Objective map. |
| Plan de tir | Plane of fire. |
| Plan de site | Plane of site. |
| Planchette carroyée | Squared sheet. |
| Planchette de tir | Firing board. |
| Planchette topographique | Plane table. |
| Plateau | Plateau. |
| Poids de la section droite | Sectional density. |
| Point d'alignement | Marker. |
| Point de déclinaison | Declinating point. |
| Point de chute | Point of fall. |
| Point moyen | Center of impact. |
| Point moyen du tir fusant | Burst center. |
| Point de pointage | Aiming point. |
| Point de réglage | Adjusting point. |
| Point de repère | Marker; reference point. |
| Point de repérage | Referring point. |
| Point de surveillance | Base point. |
| Pointage réciproque | Reciprocal laying. |
| Portée | Range (of trajectory) (A. F. § 5). |
| Portée entièrement dépouillée | Completely stripped range. |
| Portées par coordonnées | Plotted. |
| Position de crête | Crest position. |
| Position de grand défilement | Position of deep defilade. |
| Possibilités de tir | Possibilities of fire. |
| Poste de commandement | Command post. |
| Poste d'observation auxiliaire | Auxiliary observation post. |
| Préparation du tir | Preparation of fire. |
| Projectile | Projectile. |
| Projectile fumigène | Smoke shell. |
| Projectile de réglage | Adjusting shell. |
| Quadrant | Quadrant. |
| Rafale | Volley. |
| Rapporteur | Protractor. |

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| | |
|---|---|
| Rapporteur de parallaxe | Parallax protractor. |
| Rayonnement | Direction and distance method. |
| Rayonnement direct | Direction and distance method (directly). |
| Rayonnement inverse | Direction and distance method (inversely). |
| Recoupement | Resection. |
| Rectangle de dispersion | Rectangle of dispersion. |
| Réduit | Strong point. |
| Régimage des canons | Calibration. |
| Régime du canon | Calibration errors of a piece. |
| Réglage | Adjustment. |
| Réglage en direction | Deflection adjustment. |
| Réglage d'encadrement | Bracket adjustment. |
| Réglage fusant | Time fire. |
| Réglage fusant des obus explosifs. | Time shell adjustment. |
| Réglage percutant d'encadrement. | Percussion bracket adjustment. |
| Réglage percutant de précision | Percussion precision adjustment. |
| Réglage en portée | Fire for adjustment.<br>Range adjustment. |
| Réglage de précision | Precision or complete adjustment. |
| Réglage par le son | Sound ranging. |
| Règle à dessins | Straight edge. |
| Règle à éclimètre | Telescope alidade. |
| Règle graduée | Scale. |
| Relais de feu | Relay. |
| Relèvement | Three-point method. |
| Relèvement non orienté | Unoriented three-point method. |
| Remblai | Embankment. |
| Répartition | Distribution. |
| Repère | Marker. |
| Repère de position | Place mark. |
| Repérage sur un but témoin | Use of the witness point. |
| Repérer la pièce | Refer the piece. |
| Réseau d'observatoire | Observer system. |
| Retard | Delay. |

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| | |
|---|---|
| Rigidité de la trajectoire | Rigidity of the trajectory. |
| Rose des vents | Wind rose, or wind chart. |
| Rugueux | Firing pin. |
| Sablier | Ground sill (of dugouts). |
| Salve | Salvo. |
| Schéma des liaisons | Liaison system. |
| Section de recherche de renseignements par observation terrestre. | Flash and sound ranging groups. |
| Sitogoniomètre | Sitogoniometer. |
| Sommet de la trajectoire | Summit of the trajectory. |
| Station d'orientation | Orienting point. |
| Surveillance, en | On the base line. |
| Table de tir | Firing table. |
| Tableau | Table (of figures). |
| Tambour | Drum. |
| Tir d'anéantissement | Annihilation fire. |
| Tir d'amélioration | Improvement fire. |
| Tir d'accrochage | Fire for adjustment; used specially in connection with fire on a witness point to designate the adjustment on the objective. |
| Tir de destruction | Destruction fire. |
| Tir d'efficacité | Fire for effect. |
| Tir d'efficacité fusant | Time fire for effect. |
| Tir d'encagement | Box barrage. |
| Tir d'essai | Trial fire. |
| Tir d'interdiction | Interdiction fire. |
| Tir de harcèlement | Harassing fire. |
| Tir sur hausse unique | Fire at a single range. |
| Tir sur but fugitif | Fire on fleeting objective. |
| Tir de ratissage | Raking fire. |
| Tir fusant d'obus à balles | Time shrapnel fire. |
| Tir fusant en arrière des crêtes | Time fire behind crests. |
| Tir de neutralisation | Neutralizing fire. |
| Tir plongeant | Curved fire. |
| Tir de précision | Precision fire. |

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| | |
|---|---|
| Tir à ricochet | Ricochet fire. |
| Tir de régimage | Calibration firing. |
| Tir de réglage | Fire for adjustment. |
| Tir de riposte<br>Tir de représailles | Reprisal fire. |
| Tir systématique | Systematic fire. |
| Tir tendu | Flat fire. |
| Tir sur but susceptible de mouvement. | Fire on a transient objective. |
| Tir sur zone | Zone fire. |
| Tir sur but mobile | Fire on a moving objective. |
| Tir de vérification | Testing fire. |
| Tir vertical | High angle fire. |
| Trajectoire | Trajectory. |
| Trajectoire dans le vide | Trajectory in vacuo. |
| Tranchée de départ | Assembly trench. |
| Transport de tir | Shifting fire or shift of fire. |
| Travaux d'approche | Works of approach. |
| | |
| Usure des pièces | Wear of the pieces. |
| | |
| Vent balistique | Ballistic wind. |
| Vérification d'un angle au niveau. | Verifying an elevation. |
| Vérification des angles de pointage | Sight adjustment. |
| Visibilité | Visibility. |
| Vingtième | Twentieth (of a degree). |
| Vitesse initiale | Muzzle velocity. |
| Vitesse restante | Remaining velocity. |
| Vivacité | Quickness (of a powder lot). |
| | |
| Zone battue | Pattern (of shrapnel). |
| Zone des objectifs | Objective zone. |
| Zone d'observation | Observing sector. |
| Zone de sécurité | Safety zone. |
| Zone de surveillance | Sector. |
| Zone de dispersion en portée | Range zone of dispersion. |



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## ARTILLERY ABBREVIATIONS.

| | | |
|---|---|---|
| Art. | Artillerie. | Artillery. |
| A. A. A. | Artillerie anti-aérienne. | Anti-aircraft artillery. |
| A. C. A. | Artillerie de corps d'armée. | Army Corps artillery. |
| A. C. | Artillerie de campagne. | Field artillery. |
| A. D. | Artillerie divisionnaire. | Division artillery. |
| A. L. | Artillerie lourde. | Heavy artillery. |
| A. L. C. | Artillerie lourde courte. | Heavy howitzers. |
| A. L. L. | Artillerie lourde longue. | Heavy guns. |
| A. L. G. P. | Artillerie lourde à grande puissance. | High power heavy artillery. |
| A. L. T. | Artillerie lourde à tracteurs. | Tractor heavy artillery. |
| A. L. V. F. | Artillerie lourde sur voie ferrée. | Railway artillery. |
| D. C. A. | Défense contre avions. | Anti-aircraft defense. |
| G. C. T. A. | Groupe de canevas de tir d'armée. | Army topographical section. |
| P. C. | Poste de commandement. | Command post. |
| P. O. | Poste observation. | Observation post. |
| R. G. A. L. | Réserve générale artillerie lourde. | (No equivalent organization at present.) |
| S. R. A. | Service de renseignements de l'artillerie. | Artillery intelligence service. |
| S. R. L. | Section de repérage par les lueurs. | Flash ranging group. |
| S. R. S. | Section de repérage par le son. | Sound ranging group. |
| S. R. O. T. | Section de recherche de renseignements par l'observation terrestre. | Flash and sound ranging groups. |



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| | | |
|---|---|---|
| S. T. C. A. | Section topographique de corps d'armée. | Army Corps topographical section. |
| T. P. S. | Télégraphie par le sol. | Earth telegraphy. |
| T. S. F. | Télégraphie sans fil. | Radio telegraphy. |
| 155 C. | 155 court. | 155 howitzer. |
| 155 C. S. | 155 court Schneider. | 155 Schneider howitzer. |
| 155 C. T. R. | 155 court tir rapide. | 155 rapid firing howitzer. |
| 155 G. P. F. | 155 grande puissance Filloux. | 155 high power Filloux. |

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# CONVENTIONAL SIGNS OF MAPS.






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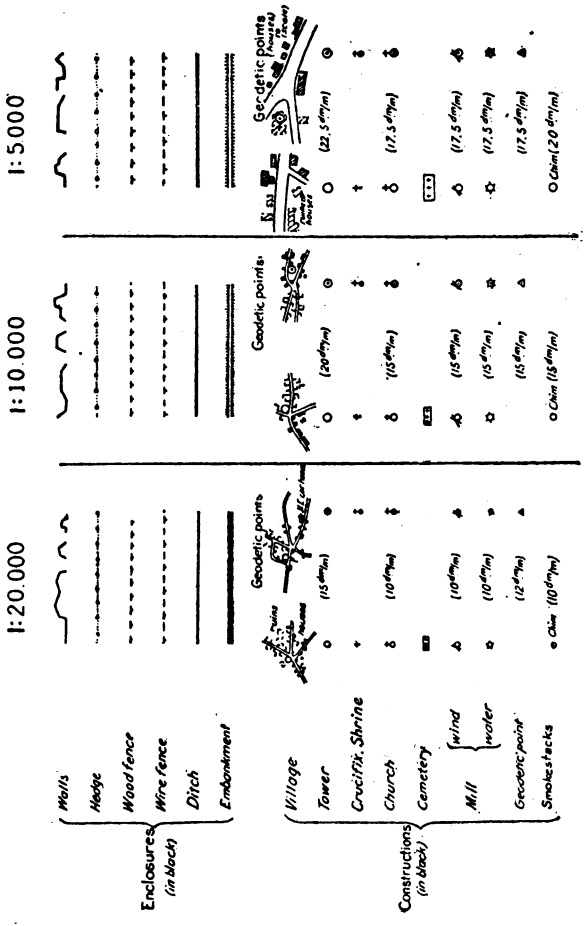
1:20.000
1:10.000
1:5.000
Enclosures (in black)
Walls
Hedge
Wood fence
Wire fence
Ditch
Embankment
Constructions (in black)
Village
Tower
Crucifix, Shrine
Church
Cemetery
Mill
wind
water
Geodetic point
Smokestacks
Geodetic points
Geodetic points
Geodetic points
(15 dm/m)
(10 dm/m)
(12 dm/m)
Chim (10 dm/m)
(20 dm/m)
(15 dm/m)
(15 dm/m)
(15 dm/m)
Chim (15 dm/m)
(22.5 dm/m)
(17.5 dm/m)
(17.5 dm/m)
(17.5 dm/m)
(17.5 dm/m)
Chim (20 dm/m)

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| | | 1:20.000 | 1:10 000 | 1:5.000 |
|---|---|---|---|---|
| Enemy's Works (in blue) | Dugouts, shelters | | | |
| | Trous de loup, Military Pits | | | |
| | Observation posts, commanding posts | o Obs □ P.C | o Obs □ P.C | o Obs □ P.C |
| | Shell holes, mine craters | | | |
| | Emplacement for (exceptionally on 20000) Machine guns, lance bombs | ⅄ M.G δB | ⅄ M.G δB | ⅄ M.G δB |
| | Emplacement for (exceptionally on 20000) Revolving cannon, single guns | ⌀ C.R ⌖ | ⌀ C.R ⌖ | ⌀ C.R ⌖ |
| | Railways (in black) Standard gauge | | | |
| | Railways (in black) Narrow gauge | | | |
| Works French (in red) | Front lines | in black or in red | in black or in red | in black or in red |
| | Firing trenches | | | |
| | Communication trenches principal | | | |
| | Communication trenches secondary | | | |
| | Abandoned trenches | | | |
| | Railways Standard gauge | | | |
| | Railways Narrow gauge | | | |

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## Various works and parts of a prepared terrain

Wire entanglements ——— xxxxxxxx

Turnout in a communication trench ———

Steps to get in or out of a communication or fire trench ———

Crossing in a communication or fire trench ———

Shelter ———

Command Post
- of Battalion ———
- of Regiment ———
- of Brigade ———
- of Division ———
- of Army Corps ———

Infantry observation post ———

Artillery observation post
- Occupied ———
- Prepared ———

Machine gun shelter
- Occupied ———
- Prepared ———

Emplacement for trench mortars
- Occupied ———
- Prepared ———

Munition depots
- Cartridge ——— cart
- Grenades ——— gr
- Trench engines Tr

Depot of tools and materials ———

Subsistence depot ———

Water supplies ———

Dressing stations ——— P S

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## Headquarters and Staffs

Commanding general (General Headquarters) ———

Headquarters of group of armies. ———

Headquarters 2nd Army ———

Director of Supply Service 2nd Army. ———

Headquarters 7th Army Corps ———

Headquarters 3rd Division (1st of the Army Corps) ———

Headquarters 4th Division (2nd of the Army Corps) ———

Headquarters 53rd Division (3rd of the Army Corps)

Headquarters 65th Separate Division. ———

Headquarters 4th Cavalry Division ———

Staff, 25th Infantry Brigade ———

Staff, 3rd Cavalry Brigade ———


## Infantry

Company of Infantry ———
Company of Chasseurs ———
Group of Cyclists ———
Battalion of Infantry ———
Battalion of Chasseurs ———

## Cavalry

Squadron of Cavalry. ———
Regiment of Cavalry ———
Small group. ———

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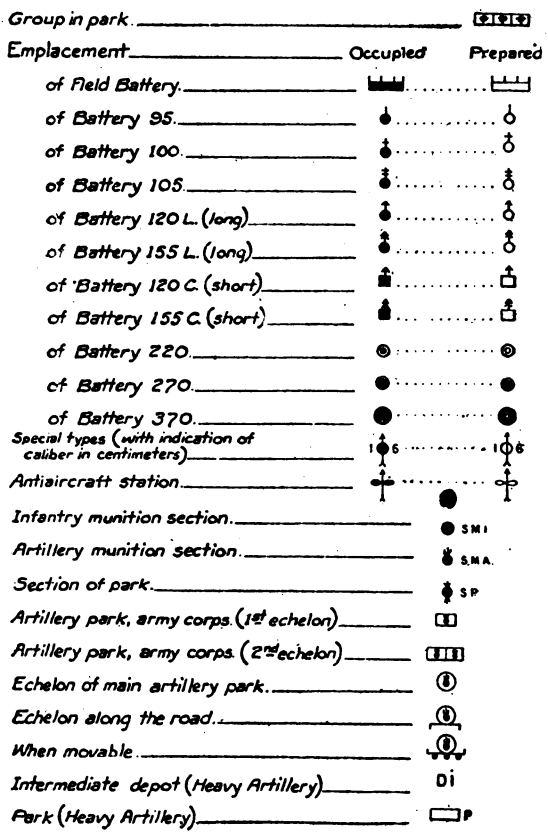
## Artillery

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## Engineers.

Company of Engineers.

Searchlight section.

Telegraph detachment of army corps. 

Telegraph section. (Army) 

Telegraph section of 2nd line

Field radio station. 

Bridge equipage.

Army corps engineer park

Army engineer park

## Medical Service

Ambulance 

Hospital section. 

Group of stretcher bearers.

Evacuation hospital

Section of evacuation hospital

Reserve personnel

Reserve material

Hospital in railroad station

Sanitary train.

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## Aviation

Squadron

Aviation park

Bombing group

Park of bombing group

Landing field

Captive balloon

## Automobile Service

Section supplying fresh meat

Sanitary section automobile

Section for transportation of material

Section for transportation of personnel

Section of automobile park

## Service of Administration and Supply

Section of subsistence supply train

Section of auxiliary subsistence supply train

Cattle park

Army field bakery

## Miscellaneous

Regimental train

Field remount depot

Headquarters of advanced base beyond rail-head

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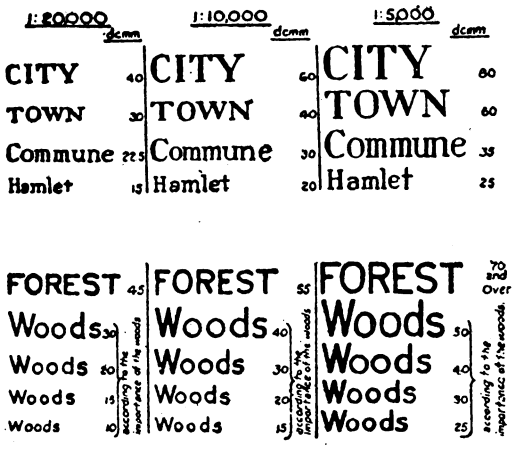


1 For the Plans Directeurs taken from maps on scale of 1 to 20,000 the conventional cartographic signs are to be the same as those on the maps used

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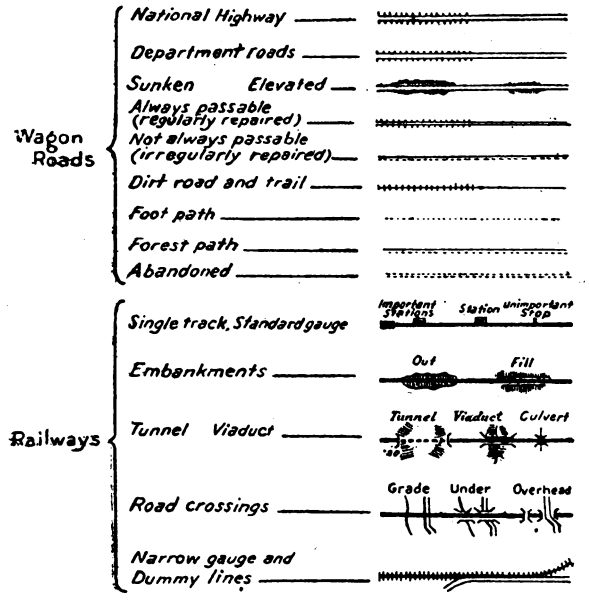
SCALE 1:80,000 and Black 1:50,000 French Maps

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Hydrography

- Large River
- Creek
- Intermittent Stream
- Waterfall — Cascade
- Important navigable canal
- Navigable canal — Tunnel, P, Basin, Aqueduct, Port
- Irrigation Ditch
- Aqueduct — Open, Covered
- Ditch, Dike — Ditch, Dike
- Canal — dike, ditch
- Bridges
- Ferry
- Dam
- Ford
- Lake, Pond
- Pool, Reservoir, Cistern — P, R, C

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SCALE 1:80,000 and Black 1:50,000 French Maps

Works and Structures

- Church, steeple or belfry light house, harbor lights
- Chapel or hermitage, Oratory, important tomb
- Crucifix, Cross tomb, Statue of Virgin
- Cemetery
- Chateau or large house
- Farm house
- House or isolated structure
- Beacon, chimney monument or tower
- Wind Mill
- Mill (waterpower)
- Ironworks, factory (hydraulic power)
- Factory (nonhydraulic power)
- Telegraph semaphore
- Cave, underground quarry, den, mine, shaft, entrance to gallery
- Lime-kiln, plaster-kiln
- Fountain, well, spring
- Ruins



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SCALE 1:80,000 and Block 1:50,000 French Maps

Fences
- Stone
- Ditch
- Bank
- Hedge
- Trees

Geodetic Points
- Belfry, church, lighthouse
- Chapel
- Triangulation points
- Secondary points

Note:
The figures which accompany the symbols above, express in meters the hight above the level of the sea

Classification of place names
- PREFECTURE PF
- SOUS-PREFECT SP
- CANTON CT
- Commune

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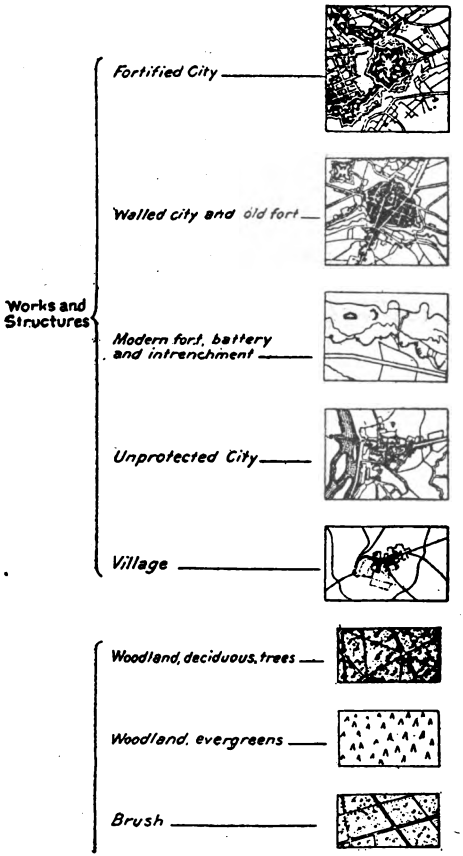


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Land Classification

Cultivated

Inundated

Orchards

Hedges and gardens

Peat bogs

Swamp

Salt marsh

Uncultivated land and cliff

Sand dunes and sand

Reefs above and under water

Mountains

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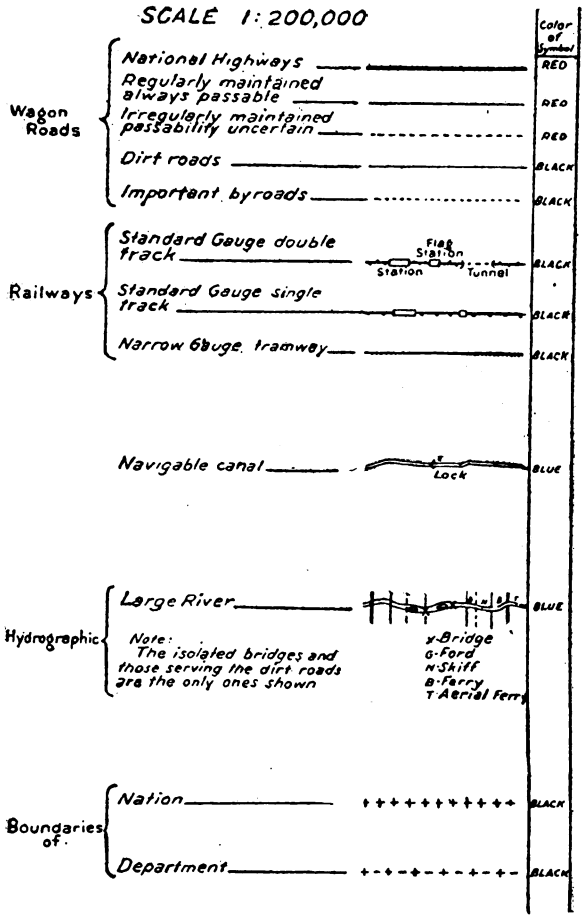


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SCALE 1:200,000

| | | | Color of Symbol |
|---|---|---|---|
| Works and Structures | Church in village | o | BLACK |
| | Isolated church or chapel | ♁ | BLACK |
| | Important Shrine | † | BLACK |
| | Castle | ♝ | BLACK |
| | Observatory tower | ♝ | BLACK |
| | Ruin | ♚ | BLACK |
| | Foresters house | ⅄T | BLACK |
| | Wind mill | ⅄ | BLACK |
| | Water power mill, saw mill | ⌑ | BLACK |
| | Works, Factory | ⌑ | BLACK |
| | Fortifications | ⌑ | BLACK |
| | Elevation figures | 128 | BLACK |
| | Figures of population in thousands | 0,7 | BLACK |

| | | |
|---|---|---|
| Classification of Place Names | City | VILLE. VILLE. |
| | Small city, Market town | PETITE VILLE. BOURG. |
| | Village, Commune, Fort | Village. Commune. fort. |
| | Mountain, Forest, Large River | Montagne. Forêt. Fleuve. |
| | Hamlet, Important River, Woods | Hameau Rivière importante Bois. |
| | Small Mtn., Hill, Cliff, Peak | Mont. Col. Rocher. Pic |
| | Glacier, Lake | Glacier. Lac. |

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## LEGEND FOR MAP OF SUPPLY SYSTEM OF FRENCH ARMY

| | | Color of Symbol |
|---|---|---|
| Front | | RED |
| Limit of army sector | | BLUE |
| Limit and line of etape zone | | BLUE |
| Standard gauge Rwy. | Standard gauge | RED |
| | Ration refilling point (with depot for reserve stores) | RED |
| | Station used as refilling point without depot for reserve stores | RED |
| Railway 60cm. gauge | Animal traction | RED |
| | Mechanical traction | RED |
| | Important station | RED |
| | Secondary station | RED |
| | Secondary station with telephone connection | RED |
| | Siding ('dead end) | RED |
| | Rail dump — D.R. | RED |
| | Unloading platform | RED |
| | Important station with unloading platform | RED |
| Crossings for | Infantry — Inf | RED |
| | Cavalry — Cav. | RED |
| | Horse drawn vehicles and small ambulances — V. H. | RED |
| | Heavy artillery with indications of type $A'A^2B'B^2C'C^2$ — A.L.G.R | RED |
| | 7 ton trucks and autos — V. A.7 | RED |
| | 9 ton trucks and autos — V. A.9 | RED |
| | 10 ton trucks and autos — V. A.10 | RED |
| Road ballast dump | M | BLUE |

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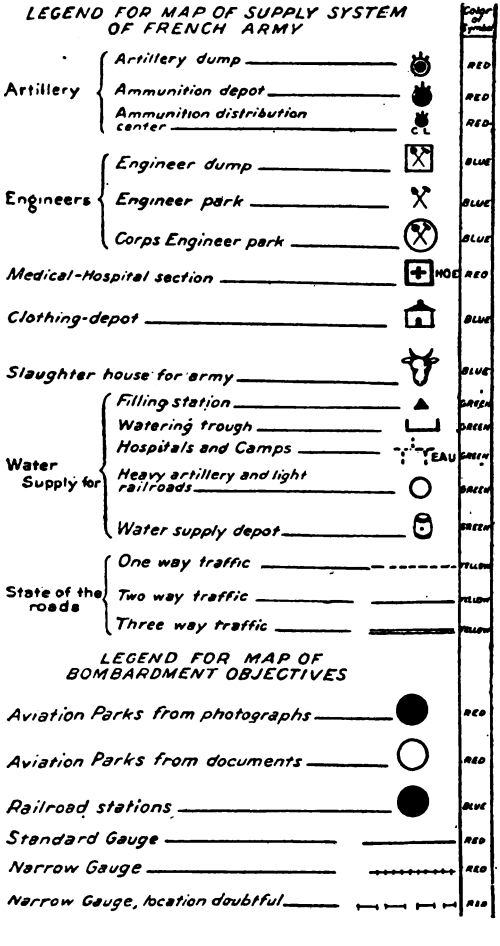


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LEGEND FOR MAP OF ENEMY FIRST POSITIONS

| | Color of Symbol |
|---|---|
| The trenches and covered communications are indicated by green hatching | GREEN |
| Dugouts, cellars and inhabited houses | GREEN |
| Machine guns in the open | RED |
| Machine guns under cover | GREEN RED |
| 37 mm. Gun | RED |
| Observation post | RED |
| Trench mortar in the open | RED |
| Trench mortar under cover | GREEN RED |
| Distribution center | RED |
| Headquarters | GREEN RED |
| Concealed battery | RED |
| Concealed battery in casemate | GREEN RED |
| Emplacement, isolated | RED |
| Anti-aircraft gun | RED |
| Ammunition depot | RED |
| Telephone lines, buried | RED |
| Telephone lines in the open | RED |

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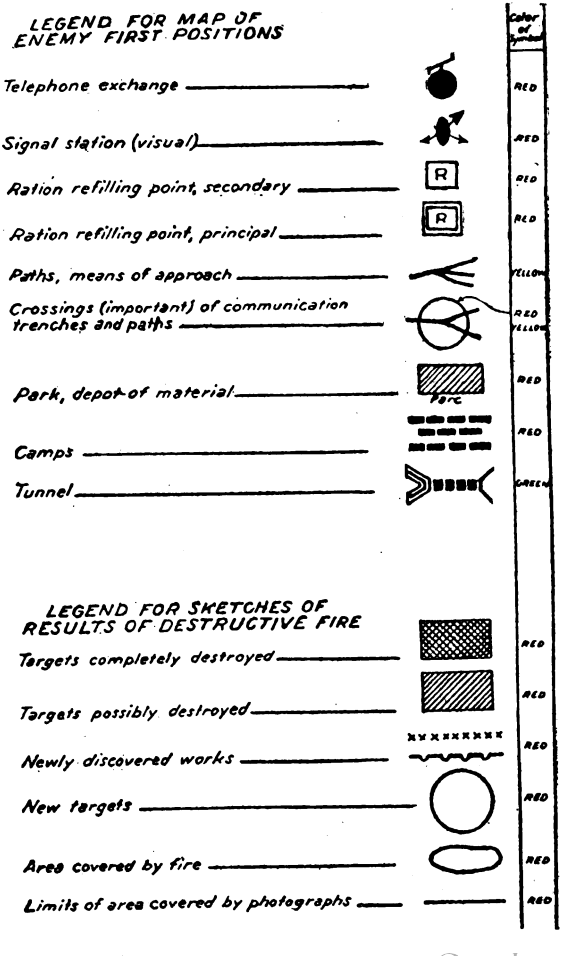


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## LEGEND FOR ACTIVE HOSTILE BATTERY SHEET WITH DIRECTION OF FIRE

| | | Color of Symbol |
|---|---|---|
| Caliber not determined | | BLUE |
| Field artillery, caliber 77 mms. |  | BLUE |
| Field artillery, caliber 105 mms. |  | BLUE |
| Heavy artillery, caliber 150 mms. |  | BLUE |
| Heavy artillery, caliber 210 mms and over |  | BLUE |
| Anti-aircraft section | | BLUE |
| Batteries seen to be in action during the period of ____ to ____ — Having already fired during the preceding period |  | RED BLUE |
| Batteries seen to be in action during the period of ____ to ____ — Inactive during the preceding period but having fired previous to that |  | RED BLUE |
| Batteries seen to be in action during the period of ____ to ____ — New |  | RED |
| Battery inactive during period ____ to ____ but active during preceding period |  | BLUE |

28 - Emplacement known to be active during the period
110 - Total number of emplacements ____ 28/110

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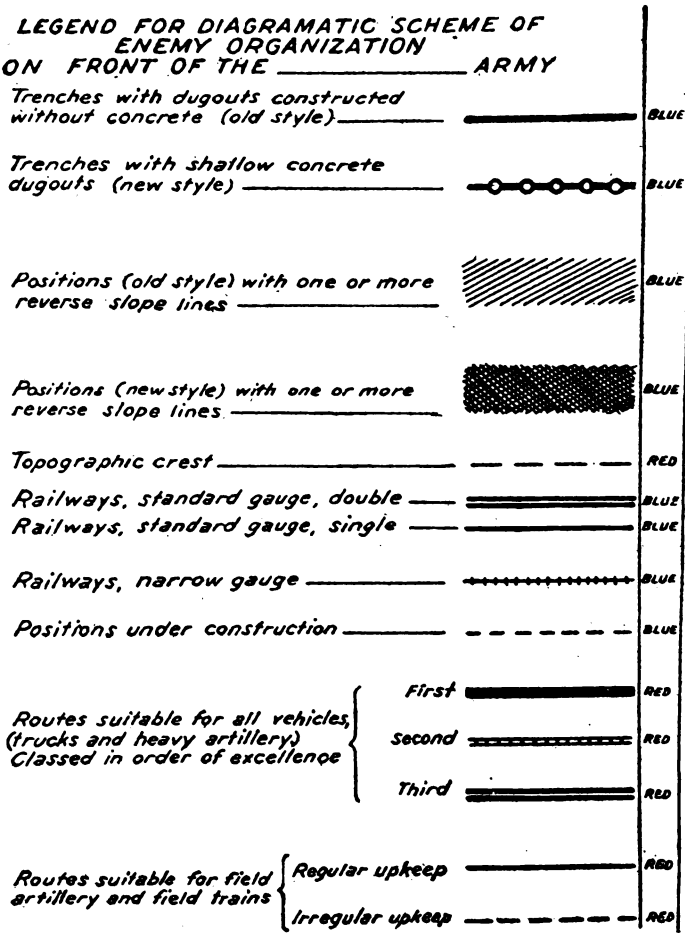
## LEGEND FOR DIAGRAMATIC SCHEME OF ENEMY ORGANIZATION ON FRONT OF THE _____ ARMY

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## LEGEND FOR GENERAL MAP OF ARTILLERY OBJECTIVES

| | Color of Symbol |
|---|---|
| Observation post | RED |
| Munition depot, position unconfirmed | RED |
| Munition depot, position confirmed | RED |
| Bridge (wagon traffic) | RED |
| Foot bridge | RED |
| Aviation Field, position unconfirmed | RED |
| Aviation Field, position confirmed by photography | RED |
| Railway — standard gauge (Gare) | RED |
| Railway — narrow gauge | RED |
| Collection of paths | YELLOW |
| Camp, Cantonment, Bivouac | RED |
| Junction of roads or tracks (paths) | YELLOW |
| Telephone central | RED |
| Signal Station (visual) | RED |
| Artillery emplacement (active) position from photographs | BLUE |
| Artillery emplacement (active) position otherwise determined | BLUE |
| Artillery emplacement, prepared, position from photographs | BLUE |
| Anti-aircraft gun | BLUE |
| Dugouts | BLUE |
| Telephone line | BLUE |

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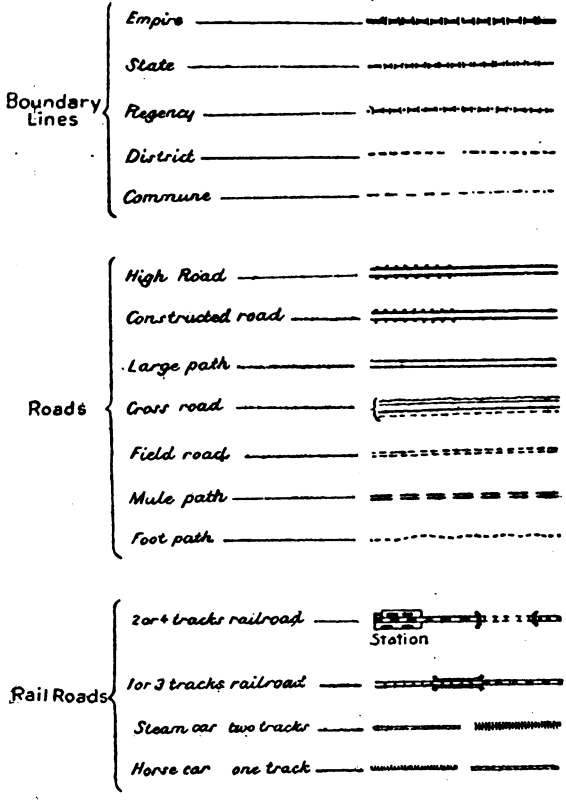
## 1:25.000

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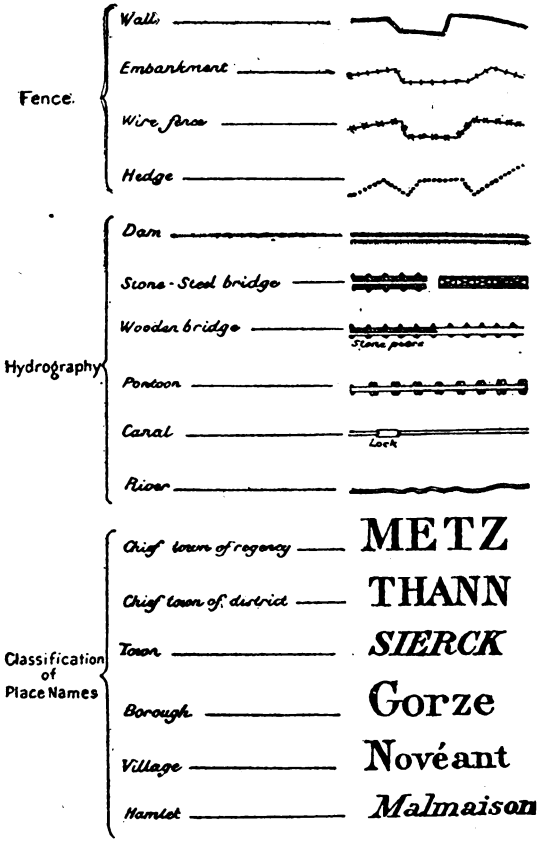
# GERMAN MAPS
## 1:25.000

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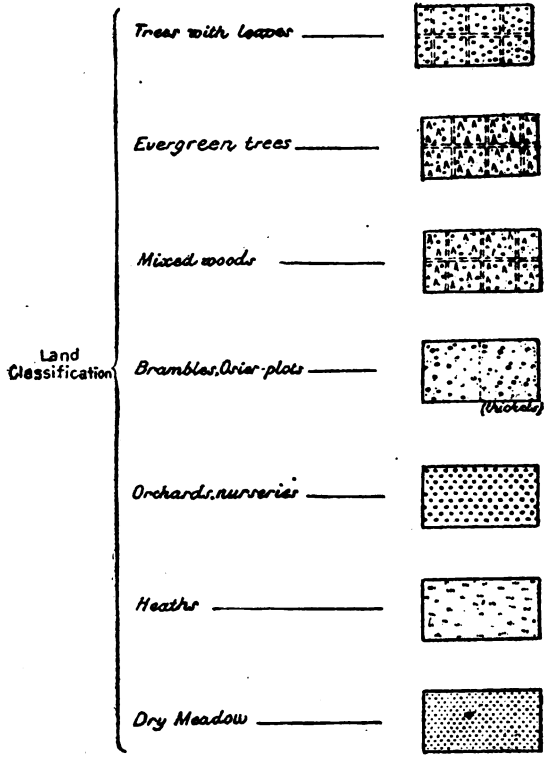
## 1:25.000

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# GERMAN MAPS 1:25.000

Land classification

- Wet Meadow
- Swamp
- Vineyard
- Hop-ground
- Garden (plain)

## ABBREVIATIONS

| | |
|---|---|
| Street. Road | Str. |
| Advanced Work | V. W. |
| Farm | Vw. |
| Small Pond | W. |
| Inn | Whs. |
| Wash-house | Wasch H. |
| Little — Kl. — Big (large) | Gr. |
| Superior | Ob. |
| Inferior | Unt |
| Tile Kiln | Zgl. |

Terminations of words

| | | |
|---|---|---|
| Hs. — Haus | Hm. - Heim | Bch. - Bach |
| Hn Hausen | Df — Dorf | Bg. — Burg |



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# GERMAN MAPS
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## ABBREVIATIONS

| | |
|---|---|
| Bailiwick | A |
| Brook | B. |
| Mountain | B |
| Station | Bhf. |
| Gatesman house | B.W |
| Manœuvring ground | Exerz. Pl |
| Mill | Fbr. |
| Ford | Ft. |
| Mountain | Gb. |
| Property Enclosure | G. |
| Halting Place | H.P. / H.p |
| Hunting residence | Jagdhs |
| Ridge. Top | K. |
| Barrack | Kas. |
| Service powder store house | K.P.M. |
| Periodical Pond | Period T. |
| Marl-pit | Mgr. |
| Clay Quarry and Marl-pit | L.u Mgl. Gr. |
| Sheepfold | Schaf. |
| Castle | Schl. |
| Lock | Schloe. |

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# GERMAN MAPS
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## SIGNS

Miscellaneous Symbols

- Church with steeple
- Church without steeple
- Chapel — Kap.
- Wind-mill — W.M.
- Water-mill — M.
- Tannery — L.M.
- Saw-mill — S.M.
- Oil-mill — O.M.
- Dyeworks — W.M.
- Paper-mill — Pap.M.
- Gun Powder — Po.M.
- Forge
- Forester — F.
- Forest Sub-Inspector — O.F.
- Forester — W.W.
- Meadow-keeper — W.W.
- Castle
- Observatory, Tower
- Ruins — R.

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# GERMAN MAPS
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## SIGNS

Miscellaneous Symbols

- Lone Tree
- Important battlefield
- Old Trench
- Monument
- Mine (mining) { The legend shows the kind of ore
- Stone quarry — Stbr.
- Pit and Ditch — Gr.
- Clay quarry — Lgr.
- Sand quarry — Sgr.
- Gravel quarry — Kiesgr.
- Rocks
- Christian cemetery — Khf.
- Jewish cemetery — Khf.
- Lime-Kiln — K.O.
- Tar-mill — T.O.
- Triangulation Point
- Fountain, Well, Spring
- Orienting Post — f.
- Oratory
- Fort
- Battery

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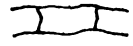
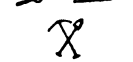
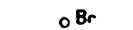
# CONVENTIONAL SIGNS COMMONLY USED ON GERMAN MAPS.

| | | Color of Symbol |
|---|---|---|
| Fire and communication trenches prepared for defence. } (Graben). | | RED<br>RED |
| Ordinary communication trenches (Weg). The distinction between fire and other trenches is not always made. |  | RED |
| Wire entanglement. | | RED |
| Trench railway (Feld-bahn). | | RED |
| Battery fixed by photography. | | RED |
| Heavy Minenwerfer. | | RED |
| Light Minenwerfer | | RED |
| M.G. (Occasionally). |  | RED |
| Grenade store (or shell magazine) | | RED |
| Screen from view. | | RED |
| Telephone station with cable. | | RED |
| Searchlight. |  | RED |
| Pioneer dump. |  | RED |
| Dressing station. | | RED |
| Well. |  Br | RED |
| Headquarters. Usually some form of circle with flag The number of circles increases with the importance of the H.Q. but the signs vary largely. | | RED |
| Coy. Commander. | K F | RED |
| Shaft of mine. | | BLACK |
| Unsafe ground with mine shafts. | | BLACK |
| Turnpike. | Ch Hs | BLACK |



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## CONVENTIONAL SIGNS COMMONLY USED ON GERMAN MAPS.

| | | Color of Symbol |
|---|---|---|
| 3·7 cm. Revolver Gun. | | RED |
| 5 cm. Belgian Gun. | | RED |
| 7·7 cm. Field Gun. | | RED |
| Anti-Aircraft Gun. | | RED |
| 9 cm Field Gun. | | RED |
| 10·5 cm. Light Field Howitzer. | | RED |
| 10 cm. Gun. (newer pattern). | | RED |
| 12 cm. Gun. | | RED |
| 12 cm. Belgian Gun. | | RED |
| 15 cm. "Ringkanone." | | RED |
| 15 cm. Long Gun. |  | RED |
| 15 cm. Heavy Field Howitzer.('13). | | RED |
| 21 cm. Mortar (old pattern). | | RED |
| 21 cm. Mortar (newer pattern). | | RED |
| 90 mm. and 95 mm French Guns. | | RED |

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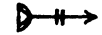
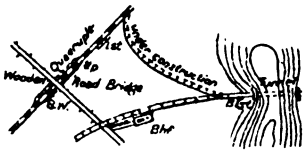
## CONVENTIONAL SIGNS COMMONLY USED ON GERMAN MAPS.

| | | Color of Symbol |
|---|---|---|
| 10 cm. Gun (older pattern) | | RED |
| 13 cm. Gun. | | RED |
| 15 cm. Gun (i.S.L.). |  | RED |
| 15 cm. Russian Gun. |  | RED |
| 15 cm. Heavy Field Howitzer (older pattern) | | RED |
| 30·5 cm Mortar. |  | RED |
| or M 42 cm. Mortar. | | RED |
| Barn. | Sch | BLACK |
| Brick-kiln | Ziegel | BLACK |
| Telegraph detachment. |  | BLUE |
| Field signalling detachment. | | BLUE |
| Wireless telegraph station |  | BLUE |

Bhf. Bahnhof (Station)
Hp. Haltepunkt (Stopping place)
Blst. Blockstation (Block signal station)
Lst Ladestelle (Loading platform).
B W Bahnwarter (Plate layer's hut)

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# CHART SHOWING LINES OF EQUAL MAGNETIC DECLINATION

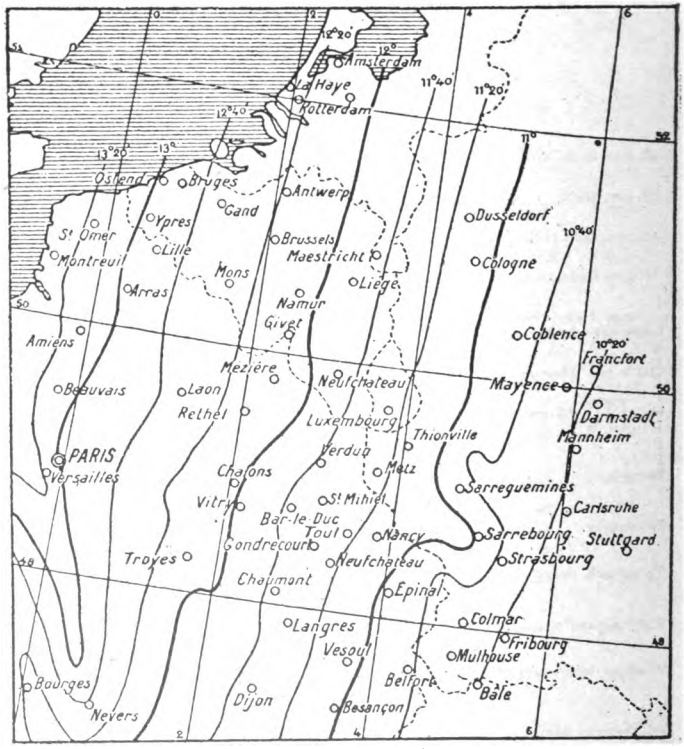


CHART SHOWING LINES OF EQUAL MAGNETIC DECLINATION, JULY 1918

*NOTE.*

Declination 15° west.

Chart may be used without correction for the year 1918 when declination to $^1/_3$ degree is desired



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